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A COMPUTERIZED FEED-DELIVERY AND MANAGEMENT SYSTEM FOR FEEDLOTS

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A COMPUTERIZED FEED DELIVERY AND INFORMATION MANAGEMENT SYSTEM FOR BEEF FEEDLOTS

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ABSTRACT

A system was obtained that allowed information to be recorded at a beef feedlot. The system contained two mobile computers and a base computer. One mobile computer allowed residual feed quantities to be recorded and sent to the base computer. The second mobile computer allowed the quantities of feed ingredients used in loads of feed to be recorded, along with the quantities of feed delivered to pens of cattle.

Feed-prediction software was written for this project that automatically determined feed quantities and ration formulations needed by pens of cattle. The software used information gathered by the two remote computers and a set of programmed management rules to determine ration formulations and feed quantities needed by the pens of cattle.

The feed-prediction software was evaluated on two occasions. On the first evaluation, it was found that the feed-prediction software did not increase feed predictions at a rate fast enough to match the appetites of the cattle. It was also found that the feed-prediction software reduced feed predictions too greatly when residual feed quantities were too large.

On the second evaluation, daily feed predictions made by the feed-prediction software were compared to those made by human experts. During this 56-day evaluation, the feed-prediction software predicted an average of 10.80 kg of feed per animal per day, while the human experts predicted an average of 10.85 kg of feed per animal per day. The feed-prediction software increased predicted feed quantities 99 times, with the feed being increased by 2.5% on average. The human experts increased feed predictions 154 times, with the feed being increased by 4.8% on average. When feed quantities were decreased, the feed-prediction software decreased feed 136 times, with the feed being decreased by 6.7% on average. The human experts decreased feed 140 times, with the feed being decreased by 5.2% on average.

During the final evaluation at a commercial feedlot, daily feed predictions made by the feed-prediction software were compared to those made by human experts. During this 35-day evaluation, the average quantity of feed assigned by the human experts and the feed-prediction software was 10.83 kg of feed per animal per day. The feed-prediction software increase predicted feed quantities 92 times, with the feed being increased by 7.2 % on average. The human experts increased feed quantities 72 times, with the feed being increased by 8.5% on average. When feed quantities were decreased, the feed-prediction software decreased feed quantities 52 times, with an average decrease of 8.9%. The human experts decreased feed quantities 40 times, with an average decrease of 7.6%.

Software-based feed prediction for beef cattle is promising. However, refinements are needed to ensure that the feed-prediction software is able to make feed predictions that match the appetites of the cattle more closely. Further testing, in independent trials, is required to compare the performance of the feed-prediction software with feeding systems currently in use.

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TABLE OF CONTENTS

ABSTRACT ii

TABLE OF CONTENTS iii

1. INTRODUCTION 1

2. OBJECTIVES 3

3. LITERATURE REVIEW 4

3.1 Management of High-Grain Diets 4
3.1.1 Starting Cattle on Feed 4
3.1.2 Determining Feed Quantities 4
3.2 Diseases Caused by Acidosis 5
3.2.1 Bloat 5
3.2.2 Liver Abscesses 5
3.2.3 Laminitis 5
3.3. Factors Affecting Feed Intake 6
3.3.1 Rumen Capacity and Feed Digestibility 6
3.3.2 Net Energy Concentration and Forage-to-Concentrate Ratio 6
3.3.3 Lipostatic Control of Feed Intake 6
3.3.4 Environmental Effects 7
3.3.5 Timing and Frequency of Feed Deliveries 7
3.3.6 Processing and Mixing of Feeds 8
3.4 Utilization of Feed Energy Within the Ruminant 8
3.5 Homeothermy 9
3.6 Electronic Identification and Monitoring of Farm Animals 11

4. RESEARCH PROJECT SYSTEM DESCRIPTION 13

4.1 Commercial System 13
4.2 Software Developed at University of Saskatchewan 15
4.3 System Databases 16
4.3.1 Pen Inventory Table 16
4.3.2 Feed Commodities Table 17
4.3.3 Ration Table 18
4.3.4 Ration Ingredient Table 18
4.3.5 Load Archive Table 19
4.3.6 Archival Table 19
4.3.7 Mill Tables 20
4.3.8 DMI/BW Settings Table 21
4.3.9 System Table 21

5. FEED-MANAGEMENT SOFTWARE 22

5.1 ME and DM Concentrations 22
5.2 Dry-matter Intake 24
5.3. Feed-Prediction Software 25

5.3.1 Quantifying Residual Feed 25
5.3.2 Determining Feed Quantities 26
5.4 Weight-Prediction Software 30
5.4.1 Animal Descriptors 31
5.4.2 Feed Descriptors 32
5.4.3 Dry Matter Intake and Retained Energy 33
5.5 Ration-Management Software 35
5.6. Archival Software 36

6. SYSTEM TESTING 39

6.1 Preliminary Tests 39
6.2 Early Feeding Test 39
6.3 Weight Re-evaluation Test 41
6.4 Late Feeding Test 43
6.5 Final Testing 44

7. RESULTS AND DISCUSSION 48

7.1 Early Feeding Test 48
7.1.1 Animal Body-Weight Prediction Results 48
7.1.2 Feed-Prediction Results 48
7.1.3 Feed-Delivery Accuracy 53
7.1.4 Hardware Evaluation 54
7. 2 Weight Re-evaluation Test 54
7.3 Late Feeding Test 55
7.3.1 Animal Body-Weight Prediction Results 55
7.3.2 Feed-Prediction Results 58
7.4 Results from Final Testing 59

8. CONCLUSIONS 61

8.1 Feed Prediction 61
8.2 Operator Accuracy 61
8.3 Body-Weight Prediction 62
8.4 Hardware 62
8.5 Conclusions from Final Testing 62
8.6 Future Work 62

REFERENCES 64

APPENDIX A: NETWORK HARDWARE SETUP 67

APPENDIX B: SERIAL INTERFACE 69

APPENDIX C: MILL COMPUTER SOFTWARE INSTALLATION 70

APPENDIX D: MOBILE UNIT SOFTWARE INSTALLATION 71

APPENDIX E: MOBILE-UNIT SOFTWARE OPERATION 72

APPENDIX F: MILL SOFTWARE CONFIGURATION 77

APPENDIX G: GRAPHS FROM EARLY FEEDING TEST 82

1. INTRODUCTION

The economic impact of feeding cattle in Saskatchewan is significant. Saskatchewan Agriculture, Food and Rural Revitalization (SAFRR) (2002) reported that livestock production in Saskatchewan generated 1.6 billion dollars annually in farm cash receipts. The number of cattle and calves on Saskatchewan farms was estimated to be 2.84 million head as of July 1, 2002 (SAFRR 2002). Studies carried out in Alberta suggested that a feedlot of 1100 head contributed $244,000 to the local economy and $343,000 to the province. These studies also estimated that every 1100 feeder cattle provided $300,000 in economic benefits and created 3 jobs. These studies estimated that for every job created at the feedlot, six jobs were created at the processing plant (Kohls 2000).

In North America, beef cattle are fed high-grain diets during the final phase of their growth to prepare them for market. Grain is fed to cattle because it is inexpensive, easy to transport and easy to process. Feeding cattle a high-grain diet results in more rapid growth and reduces the quantity of feed required per unit of body-weight gain (Woody et al. 1983). Grain-finished cattle produce carcasses of superior quality compared to cattle finished with forages. Steaks derived from grain-fed cattle are more tender, have a higher flavour intensity, and cook faster than steaks derived from forage-finished cattle (Berry et al. 1988).

High-grain diets are not natural for cattle because their digestive systems are more suited for the digestion of forages. The rumen is like a large fermentation vat. It contains a large microbial population that converts ingested feeds into usable compounds from which the ruminant obtains its energy. These compounds are acetic acid, propionic acid and butyric acid. Under normal conditions, the pH of the rumen is kept at a nearly neutral level: pH 6.5 to 6.8 (Stanton 1985). Saliva produced by the ruminant is alkaline in nature (pH 8.4 to 8.7) and contains buffering agents that help maintain optimal rumen pH (Stanton 1985).

When a ruminant consumes a large quantity of grain, a condition called acidosis can occur. Acidosis occurs because grain contains large quantities of starches and sugars that are rapidly converted into lactic acid by microorganisms in the rumen. When the quantity of grain ingested is large, the quantity of lactic acid produced can exceed the capacity of the rumen bacteria to process it. This results in reduced rumen pH, which kills the bacteria that were involved in digestion and impairs rumen function (Stanton 1985).

Acidosis is a concern because it can temporarily depress the animal's appetite, cause erratic feed intake, or even kill the animal (Owens et al. 1998). Acidosis can also cause liver damage. Animals with damaged livers gain weight less rapidly than those with healthy livers (Nagaraja and Chengappa 1998). Acidosis can cause bloat, which can reduce animal performance or kill the animal via asphyxiation (Cheng et al. 1998). Acidosis can also cause laminitis, a disease that causes deformities in the animal's hooves and reduces its performance. Acidosis can have a significant economic impact at the feedlot. Pritchard (1993) stated that a ten-percent increase in feed-to-gain conversion caused by acidosis could reduce profits by $26 per head.

An important tool for preventing acidosis is the development of a feed-intake history for the pens of cattle. The feed-intake history is a record of the feed

that was consumed by the pens of cattle over the feeding period. The feed-intake history is important because a digestive upset caused by an error in feeding may not be evident for several days. Without a history of how much the cattle have been consuming and how much they have been fed, it is difficult to correct the mistake (Pritchard 1993).

A large quantity of data must be collected to develop the feed-intake history in a large feedlot. The data required are:

1. the quantity of feed delivered to the pens,
2. the quantity of residual feed remaining in each pen after feeding,
3. the number of animals in each pen and
4. the feed commodities in each ration.

A large feedlot may have hundreds of bunks and feeding may occur several times per day, so the quantity of data adds up quickly. At some feedlots, the quantity of feed that is actually delivered to the feed bunks is not recorded. Instead, a target weight is recorded and feed-deliveries that differ from it are unrecorded. As a result, it is impossible for the bunk reader to determine the exact quantity of feed consumed by the cattle because the quantity that was actually delivered to them is unknown. Thus, an accurate feed intake history is not available making it difficult to determine how much feed the cattle require for subsequent feedings.

The hypothesis was that developing a software application that created a more accurate feed-intake history could minimize the problems associated with feeding high-grain diets to cattle. Further, a software-based feed-management system could assist the bunk reader by making more accurate feed predictions. Computers could be used for all of the data collection and archiving, eliminating the need for the manual entry of data into paper-based records. This could save time and reduce the errors associated with paper-based record keeping.

2. OBJECTIVES

The objectives of this project were to:

1. obtain a system of three computers connected by a wireless network that would allow the exchange of information between the three computers,
2. develop software that could record the data necessary to create a more accurate feed-intake history,
3. develop software that could predict quantities of feed needed by pens of feedlot cattle and
4. test the hardware and software components of the system at the University of Saskatchewan Beef Research Station and at a commercial feedlot.

3. LITERATURE REVIEW

3.1 Management of High-Grain Diets

High-grain diets need to be managed carefully to avoid digestive disturbances. Digestive disturbances can cause acidosis, which can cause bloat, abscessed livers or laminitis. These conditions can have an adverse affect on the health of the animal, casing poor feedlot performance or even death. These are a concern for the feedlot operator because they can lead to significant financial losses.

3.1.1 Starting Cattle on Feed

Beef cattle are fed a series of rations, called step-up rations, which increase in grain and energy content in several intermediate steps. This allows the rumen microbial population to adapt, so it can digest starchy feeds (Horton 1990). At the end of the step-up period, the cattle will be on their final high-grain finishing ration. It is expected that they should be at, or near, the mean expected dry matter intake of the finishing ration at this time.

The number of rations in a step-up series can vary between producers. Some producers will have as few as three (Horton 1990), while others may have as many as ten (Stanton 1985). Step-up rations should be fed over a period of approximately 28 to 30 days (Pritchard 1993). The time cattle spend on each ration in the series will depend on the number of rations in the step-up series and its duration. Some nutritionists state that cattle should spend three days on each step-up ration (Anonymous 1999).

When step-up rations are changed, the quantity of dry matter presented to the cattle should remain constant (Anonymous 1999). This will help to prevent the cattle from developing acidosis because it limits the quantity of energy they receive during a ration change.

3.1.2 Determining Feed Quantities

If quantities of feed delivered to cattle are increased too rapidly, their capacity to consume it might be overwhelmed and they may experience acidosis, which causes them to reduce their feed intake. As a result, the feed delivered to the cattle must be reduced so they will clean up their existing feed. When the cattle increase their appetites again, usually after a few days of reduced intake, feed quantities must not be increased too rapidly. Otherwise, the cattle can experience another episode of digestive disturbances and reduced feed intakes. This creates a cyclical or "yo-yo" pattern of feed intake that makes it difficult to establish a consistent feed-intake pattern (Horton 1990).

One method to prevent cyclical feed-intake patterns is to follow a feeding protocol that limits the rate at which feed quantities are increased. Feed increases are limited by the ratio of dry matter intake: body weight of the cattle (DMI/BW). The DMI /BW is the feed dry-matter intake of the cattle divided by their body weight. An example of a feeding protocol used in industry is as follows. According to this protocol, cattle with DMI/BW less than 2.0% should be have their feed increased as quickly as possible. When the cattle are between 2.0 and 2.35% DMI/BW, they should have their feed increased by a maximum of 10%,

relative to the quantity of dry matter fed the previous day. Feed increases can occur every second day. Cattle that are between 2.35% and 2.6% DMI/BW should have their feed increased by 5%, relative to the quantity of dry matter fed the previous day. Feed increases can occur every second day. Finally, cattle that are beyond 2.6% DMI/BW should have their feed increased by 2.5%, relative to the quantity of dry matter delivered on the previous day. Feed can be increased every second day. Some nutritionists suggest that calves that have been on feed for 35 days and yearlings that have been on feed for 20 days should have their feed quantities increased by 2.5%, relative to the quantity of dry matter delivered on the previous day. Feed can be increased every second day for these cattle (Anonymous 1999).

3.2 Diseases Caused by Acidosis

3.2.1 Bloat

Bloat is the distension of the rumen and reticulum caused by the failure to release the gases of fermentation. The fermentation of feeds within the rumen results in as much as two litres of gas per hour (Cheng et al. 1998). If gas is allowed to accumulate in the rumen it will distend and exert pressure on the diaphragm and lungs, potentially causing death by asphyxiation.

Cheng et al. (1998) reported that in a survey of feedlots containing more than 28 million cattle on the Great Plains between the years 1990 and 1993, mortalities from digestive disturbances were 0.061% of all cattle on feed. Of these mortalities, 24% were due to bloat. These authors also cited a survey of western Canadian feedlots containing more than 16,000 cattle, in which the mortality rate due to bloat was 0.1 to 0.2%.

3.2.2 Liver Abscesses

When the rumen wall is damaged by acidosis, bacteria are able to enter the animal's venous system and infect its liver where they form abscesses. Liver abscesses are puss-filled and range in size from as small as a pinprick to over 15 cm in diameter. They occur in 12 to 32% of feedlot cattle (Nagaraja and Chengappa 1998). The liver accounts for as much as 2% of the carcass weight. Livers that are condemned at the time of slaughter can be a significant financial loss (Johnson 1991). Abscesses may adhere to surrounding organs of the carcass and result in more trimmings to the carcass at the processing plant. If abscesses are ruptured during processing, they can contaminate the carcass with puss, resulting in a disruption of normal processing plant flow, costing time and money (Nagaraja and Chengappa 1998). Studies have also shown that cattle with abscessed livers had average daily gains that were lower than cattle with healthy livers (Johnson 1991). This will affect the feedlot operator because it means that the cattle are using their feed less efficiently. The cost per unit gain for these animals will be larger than those with healthy livers.

3.2.3 Laminitis

The exact causes of laminitis are not clear. It is hypothesized that it is caused by the release of bacterial endotoxins and histamines as the result of

acidosis. Laminitis is almost always the result of digestive disorders, such as acidosis. It is a hoof disease that causes damage to the laminae of the hooves. It also causes inflammation of the dermal layers within the foot and can lead to severe hoof deformities. Laminitis causes pain in the feet. Cattle suffering from laminitis have difficulty rising from a lying position and have difficulty walking normally (Blood and Radostits 1989). Presumably, cattle suffering from laminitis would have difficulty accessing feed at the feed bunk because their mobility is impaired.

3.3. Factors Affecting Feed Intake

3.3.1 Rumen Capacity and Feed Digestibility

The capacity of the rumen limits the intake of forages. Cattle consume feed until a certain quantity of distension is achieved in the rumen. Tension receptors in the rumen detect this distension and signal satiety (NRC 1987).

The rate at which feed is digested affects feed intake. Feeds that are highly digestible promote higher feed intakes because they pass rapidly through the digestive tract, freeing up space for meals. The chemical component of feeds (particularly forages) that determines the rate of digestion is neutral-detergent fibre (NDF), which is a measure of the cell wall content of the feed. The relationship between NDF and rate of digestion is negative: feeds with high NDF content are digested more slowly than those of low NDF content (McDonald et al. 1988).

Disrupting the cell-wall structure of feedstuffs by chemical or mechanical means can increase feed intake in ruminants. This increases the rate of passage of the feedstuff through the digestive tract, freeing up more space for meals. Although the rate of passage is increased, the digestibility of the feedstuff is decreased (McDonald et al. 1998).

3.3.2 Net Energy Concentration and Forage-to-Concentrate Ratio

When the net energy concentration of the diet is increased, metabolic controls become the dominant factor limiting feed-intake (NRC 1987). When high-energy finishing rations are fed these metabolic controls limit feed intake.

The ratio of forage to concentrate in the ration affects the feed intake of cattle. Cattle fed an all-concentrate diet will consume approximately the same quantity of feed energy as those fed a mixed diet containing both forages and concentrates (Pope 1985). However, the cattle consuming the all-concentrate diet will consume a smaller quantity of feed compared to the cattle consuming the mixed diet.

3.3.3 Lipostatic Control of Feed Intake

Body fat plays a role in regulating the feed intake of ruminants. It has been suggested that dry matter intake decreases 2.7% for each 1% increase in body fat between over the range of 21.5 to 31.5% body fat. Thus, careful monitoring of feed intake might indicate when cattle have reached the desired quantity of body fat and are ready for slaughter (NRC 1987).

3.3.4 Environmental Effects

Weather can affect the feed intake of cattle. Cattle may be able to sense approaching storms and will increase their feed intakes by as much as 20%. (Stanton 1985) During the storm, cattle may seek shelter instead of eating. It has been suggested that when a storm is imminent, cattle that are consuming a high-grain finishing ration should be placed onto a ration that contains less energy (Perry and Cecava 1995). This will reduce the chance of the cattle developing acidosis if they consume too much feed in anticipation of the storm. Careful management will be needed during the storm to ensure that the bunks do not become filled with uneaten feed. When cattle increase their feed intakes after the storm, care must be taken to ensure that feed quantities are not increased too rapidly.

Ambient temperature will affect the feed intake of ruminants. In general, when the ambient temperature is below the thermoneutral zone feed intake is stimulated. Feed intake is depressed when ambient temperatures are above the thermoneutral zone.

A combination of hot weather and high-moisture feeds can create problems, as well. Hot weather can cause high-moisture feeds to spoil and become unpalatable to cattle, causing them to reduce their feed intake (Pritchard 1993). Fox and Gill (1985) stated that as a general rule, a 5% decrease in feed intake due to spoiled or poor quality feeds could reduce animal weight gain by 10%. Stanton (1985) stated that a 1% decrease in feed intake, due to poor quality or spoiled feeds, would reduce animal weight gains by 1.5 to 2%. When feed spoilage is a problem, it could be beneficial to feed cattle several times per day in smaller loads so that the feed is consumed before it spoils (Fox and Gill 1985).

An adequate water supply is also important for maintaining dry matter intake. An inadequate water supply during hot weather will cause cattle to decrease their feed intakes. During cold weather, a frozen water trough will cause cattle to decrease their feed intakes (Pritchard 1993).

Other environmental factors, such as day length, are known to affect the feed intake of animals, such as deer and sheep. When day length decreases, these species tend to consume less feed. However, with cattle, this effect is not significant (McDonald et al. 1988).

3.3.5 Timing and Frequency of Feed Deliveries

Cattle are more active at dawn and dusk and they will consume the majority of their feed during these times. Peak eating patterns of cattle are more influenced by the time of day rather than the timing of feed deliveries (Schwartzkopf-Genswein and Gibb 2000).

It has been suggested that there could be some advantage to feeding cattle in the evenings. During the summer, this could be advantageous because the heat increment of feeding will be present during the coolest part of day. This reduces the total heat-load on the animal and may reduce the occurrence of heat-stress. During winter, feeding in the evenings could be beneficial because the heat increment of feeding would be present during the coldest part of the day. This

could compensate for the animal's heat loss to the environment, reducing the likelihood of cold stress.

Only a few studies have evaluated the effect of feeding cattle in the evening during the winter. In one study conducted at the University of Alberta, it was found that cattle fed in the evening had the same dry matter intake, growth rates, and feed-to-gain conversion rates as those fed in the morning (Schwartzkopf-Genswein and Gibb 2001). In another study by Pritchard and Knutsen (1995), it was found that cattle fed in the evening had improved weight gains and improved feed-to-gain conversions when compared to cattle that were fed once per day in the morning.

The number of feed deliveries per day can also affect the feed intake of cattle. Stanton (1985) stated that the digestive functions of ruminants are more efficient when meals are smaller and more frequent. Feeding less frequently encourages cattle to consume feed in larger but less frequent meals. However, such a practice may increase the occurrence of acidosis. A study conducted by Pritchard and Knutsen (1995) also found that when cattle were fed twice per day (once in the morning and once in the evening) they had better weight gains and better feed-to-gain efficiencies than cattle fed once per day in the morning or once per day in the evening.

3.3.6 Processing and Mixing of Feeds

It is important that loads of feed are mixed thoroughly. Otherwise, when feed is unloaded across the bunk, the concentration of feed commodities will vary across its length. As a result, cattle at different locations along the bunk are, in effect, consuming different rations. This causes cattle to respond unpredictably when feed quantities are changed. It can also lead to cyclical intake patterns within groups of animals in a pen that are not detectable when the feed intake of the entire pen is measured. This can cause cattle to gain weight at different rates within the pen and reach desired market conditions at different times.

The dry matter content of the ration is also important. Cattle do not like to consume rations that contain a large number of fine particles or rations that may become caked to the bottom of the bunk after exposure to saliva and the elements. Rations that contain too much moisture will also decrease feed intake (Fox and Gill 1985).

3.4 Utilization of Feed Energy Within the Ruminant

Figure 3.1 illustrates the partitioning of feed energy within the animal. The arrows on the right of the figure represent the various losses of feed energy that occur within the animal.

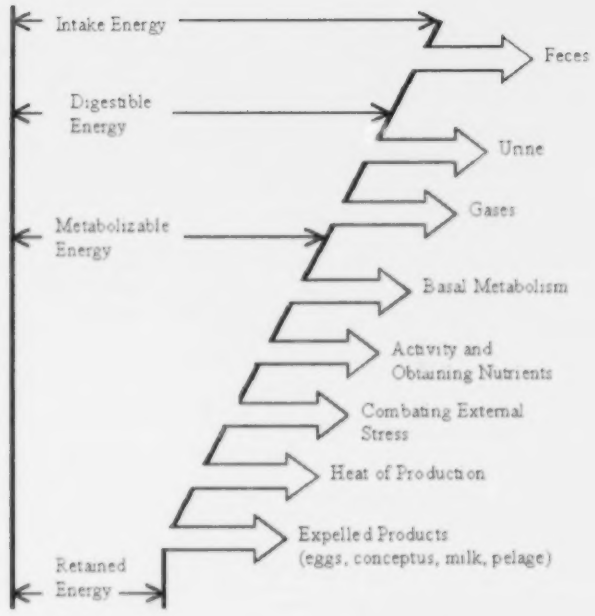


Figure 3.1: Partitioning of feed energy. Adapted from NRC (1981).

The intake energy is the energy intake of the animal per day. This is not an accurate estimate of the quantity of energy available for productive purposes because it does not take into account the energy losses that occur during digestion and metabolism (McDonald et al. 1988).

The digestible energy of a feed is the gross energy minus the energy contained in the feces. Metabolizable energy is the digestible energy of a feed minus energy contained in urine and combustible gases (McDonald et al. 1988).

The basal metabolism, or maintenance energy, is the quantity of energy required by an animal to sustain bodily functions necessary for life, such as respiration and circulation (NRC 1981). The basal metabolism is determined by measuring the quantity of heat-energy produced by animals when they are fasted. In the fasted animal, the heat-energy lost is equal to the energy extracted from its body tissues to meet its basal metabolic requirement (McDonald et al. 1988).

The retained energy is the energy available to the animal that can be used for the growth of body tissues. The quantity of metabolizable energy consumed by the animal must exceed its maintenance energy requirement in order for tissue growth to occur.

3.5 Homeothermy

Mammals attempt to maintain constant body temperature through a set of physiological processes known as homeothermy. If there is not sufficient energy intake to support body temperature, growth and production will slow (Albright 1990). Animals that have to mobilize their body reserves for energy will die when these reserves have been depleted (Stanton 1995).

The NRC (1981) defined the effective ambient temperature as the temperature of an isothermal environment without appreciable air movement that results in the same heat demand as the environment in question. The effective ambient temperature (EAT) includes such factors as dry bulb temperature, wet bulb temperature, air movement, radiation and the temperature of the surroundings (Esmay 1978).

The concept of the thermoneutral zone is critical for understanding the relationship between animals and their environment. The thermoneutral zone is defined by the NRC (1981) as the range of EAT where the heat from normal maintenance and productive functions, in non-stressful situations, offsets the rate of heat loss to the environment without requiring an increase in metabolic heat production. The thermoneutral zone is indicated in Figure 3.2.

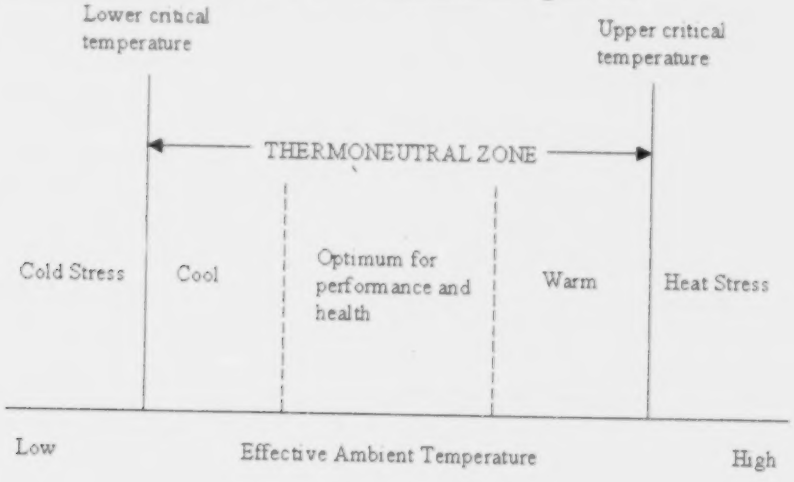


Figure 3.2: Illustration of the thermoneutral zone (NRC 1981).

The cool zone, shown in Figure 3.2, represents a range of temperatures that are below optimum, but still within the thermoneutral zone. In this zone, the animal's metabolic rate remains at the thermoneutral level. It can reduce heat-energy loss by altering its posture to reduce body surface area exposed to the environment or by making adjustments to its hair or feathers to increase their insulation value. The animal can also reduce the quantity of blood flow to its external tissues to further reduce heat-energy loss (NRC 1981).

The lower critical temperature shown in Figure 3.2 represents a boundary where the animal must increase its metabolic heat production to maintain homeothermy (NRC 1981). While in this zone, the animal is said to be cold stressed. Table 3.1 lists examples of lower critical temperatures for several types of cattle.

Table 3.1: Lower critical temperatures (LCT) for different types of cattle (NRC 1981).

Cattle Type	LCT (°C)	Cattle Type	LCT (°C)
8 mm hair, fasting	18	Fat stock, gaining 1.5 kg day^{-1}	-36
8 mm hair, maintenance	7	Beef cow, maintenance	-21
8 mm hair, full fed	-1	Dairy cow, dry and pregnant	-14
Newborn calves	9	Dairy cow, 7.6 l day^{-1}	-24
One month old calves	0	Dairy cow 30.3 l day^{-1}	-40
Fat stock, gaining 0.8 kg day^{-1}	-36		

Long-term exposure to cold stress leads to changes within the animal. For example, an animal may increase its tissue insulation (fat or skin) or its external insulation (hair coat, wool or feathers) to provide more insulation and reduce heat loss to the environment (NRC 1981).

When EAT rises above optimum, the animal is said to be in the warm zone. It can increase its rate of heat-energy loss by increasing blood flow to its external tissues, or by increasing its body surface area exposed to the environment by altering its posture. When the EAT exceeds the upper critical temperature, shown in Figure 3.2, the animal is said to be heat stressed and must employ evaporative cooling mechanisms such as panting or sweating to maintain body temperature (NRC 1981).

In a hot environment, the immediate response of heat-stressed animals is to reduce their feed intake, which reduces their metabolic heat production (NRC 1981). High-producing animals are more susceptible to heat stress because of their greater metabolic heat production from product synthesis and they are less susceptible to cold stress for this reason, as well (NRC 1981).

3.6 Electronic Identification and Monitoring of Farm Animals

Part of this project dealt with the monitoring of feed intake of pens of cattle. There are systems available that can monitor the feed-intake of individual animals. However, these systems were not readily adaptable for use with the hardware and software used in this project.

Gibb et al. (1999) described a system that was used to identify and detect individual animals when they visited a feed bunk. The system had an antenna fitted to the feed bunk. When cattle fitted with transponders extended their heads and necks into the feed bunk, the transponders were charged and activated, sending the animals' identifications back to the antenna where it was interpreted by a reader panel and relayed to a computer every 6 seconds. This allowed the system to determine the frequency and duration of bunk visitations. The system was able to read multiple transponders and all animals at the bunk could be detected concurrently. Feed intake was not measured directly.

McAllister et al. (2000) described a prototype system that had been installed at the Agriculture and Agri-Food Canada Research Centre (Lethbridge, AB). The system allowed the measurement of feed intake of individual animals.

The system had the feed bunk divided into 1.2-m sections that could be accessed by individual animals. Each section was also outfitted with load-cells that weighed the feed in each section continuously. Intake for each meal was determined from the difference between the quantity of feed present at the animal's arrival and the quantity present at its departure. Summing the animal's meals over a 24-hour period indicated daily intake.

It is important to realize that these systems do not determine the quantity of feed that the animals require. There is still a need for a system that could predict required feed quantities for cattle.

4. RESEARCH PROJECT SYSTEM DESCRIPTION

4.1 Commercial System

A system containing hardware and software components was purchased from a commercial company (LV Controls, Winnipeg, MB). The hardware component of the system consisted of three laptop computers connected by a wireless Ethernet connection. The hardware components are illustrated in Figure 4.1 The software component of the system purchased from LV Controls contained three components: Mill software, LV Link communication software and data-acquisition software called the mobile-unit software.

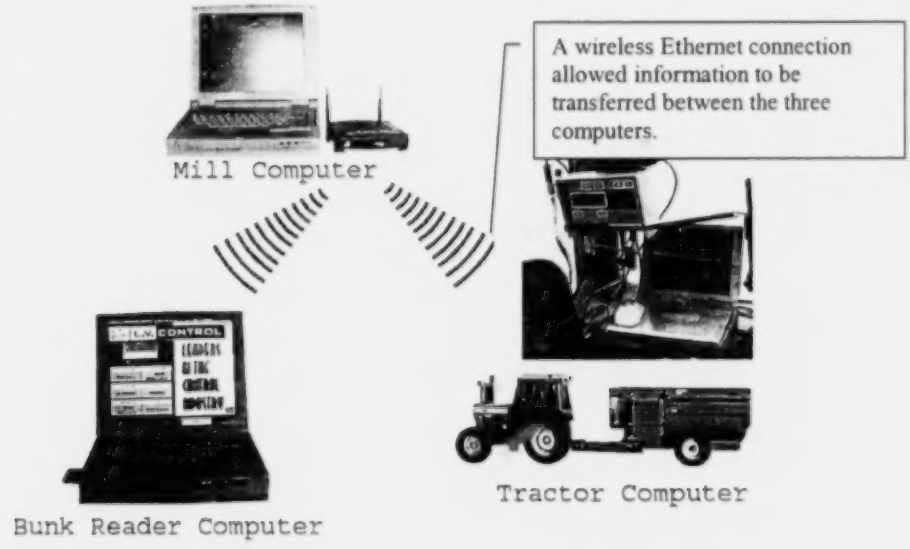

A wireless Ethernet connection allowed information to be transferred between the three computers.
Mill Computer
Bunk Reader Computer
Tractor Computer

Figure 4.1: The hardware components of the LV Controls' system.

The first computer, called the mill computer, was located in the feed mill office of the University of Saskatchewan Beef Research Centre. The mill software, as supplied by LV Controls, did not have the ability to determine the feed quantities needed by the pens. Instead, it relied upon the feedlot staff to specify the rations and feed quantities needed by the pens on each day of feeding. The mill software used this information to determine the number of loads of feed that needed to be mixed and the quantities of feed commodities needed in the loads. The software components executed by the mill computer are shown in Figure 4.2.

The mill computer also executed the LV Link communication software. This software coordinated the transfer of information between the mill computer and the other two computers over the wireless network.

The second computer, called the tractor computer, was located in the cab of the feed-wagon tractor. It executed the first component of the mobile-unit software, called the feed-mixing component, which allowed the tractor operator to

record the quantities of feed commodities used in the loads of feed. The tractor also executed the second component of the mobile-unit software, called the feed-delivery component, which allowed the operator to record the quantities of feed delivered to the pens. The software components executed by the tractor computer are shown in Figure 4.2.

An electronic scale indicator (EZ150, Digi-Star, Fort Atkins, WI) was located in the cab of the tractor. It was equipped with a serial communication port that allowed it to send weight readings to the tractor computer. The mobile-unit software used these weight readings to determine the quantities of feed commodities used in the feed loads and the portion of each load delivered to the pens. Details about the serial communication link are included in Appendix B.

The third computer, called the bunk reader computer, executed the third component of the mobile-unit software, called the bunk-reading component. This portion of the software was used on each day of feeding to record residual feed quantities in each pen and the number of cattle in them. The quantities of residual feed were estimated by the bunk reader based upon a visual inspection of the distribution of feed in the bunk. The software component executed by the bunk reader computer is shown in Figure 4.2.

The wireless Ethernet connection allowed the mill computer to send information to the bunk reader and tractor computers. The information sent from the mill computer to the bunk reader computer was a listing of the pens that needed their bunk residuals and animal numbers recorded. The information sent back from the bunk reader computer to the mill computer were the bunk residual quantities and animal numbers for the pens. The information sent from the mill computer to the tractor computer were a list of the pens that needed to be fed, the quantities of feed needed by these pens and the quantities of feed commodities needed for each feed load. The information sent back from the tractor computer to the mill computer were quantities of feed commodities used in the loads and the quantities of feed delivered to the pens. The information exchanged between the three computers is illustrated in Figure 4.3.

The tractor computer and the bunk reader computer (PA122U XCD, Toshiba America Information Systems, Irvine, CA) were equipped with wireless network cards (WPC11, Linksys, Irvine, CA). The mill computer (PA1241U CXCD, Toshiba America Information Systems, Irvine, CA) was connected to a wireless access point (WAP11, Linksys, Irvine, CA) using an Ethernet hub (3C192560, 3Com, Santa Clara, CA) and a PCMCIA Ethernet card (EC2T, Linksys, Irvine, CA). The installation of network hardware and software for the three computers is described in Appendix A.

The installation procedure for the mill software is included in Appendix C. The installation of the mobile-unit software is included in Appendix D and its operation is included in Appendix E. The configuration of the mill software is included in Appendix F.

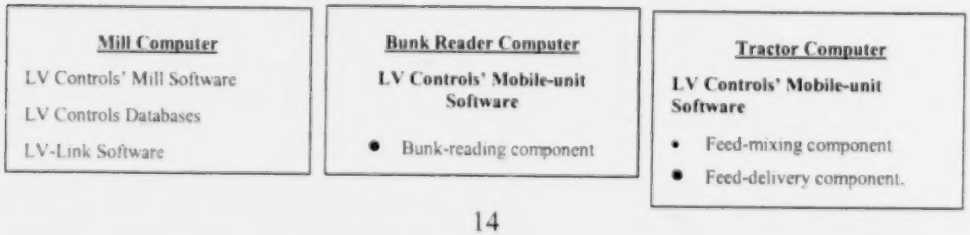


Figure 4.2: Software components installed on the three computers that were part of the LV Controls' system.

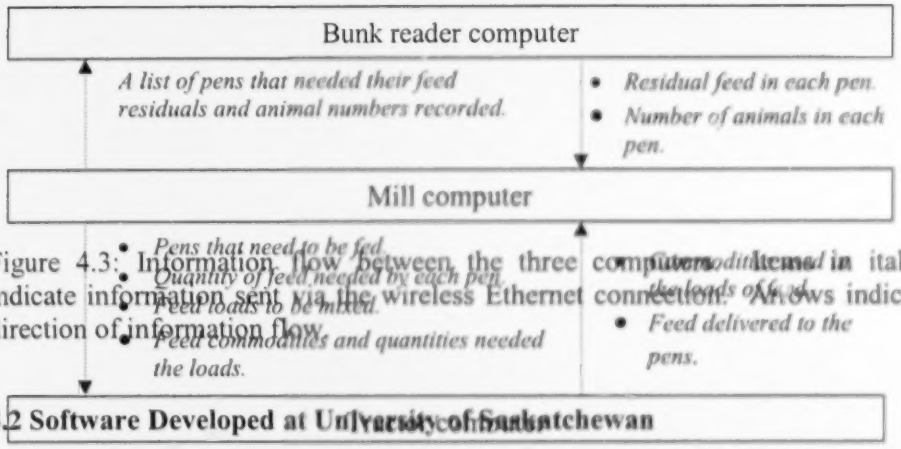

Bunk reader computer
A list of pens that needed their feed residuals and animal numbers recorded.
Residual feed in each pen.
Number of animals in each pen.
Mill computer
Pens that need to be fed.
Quantity of feed needed by each pen.
Feed loads to be mixed.
Feed commodities and quantities needed the loads.
Feed delivered to the pens.

Figure 4.3: Information flow between the three computers. Items in italics indicate information sent via the wireless Ethernet connection. Arrows indicate direction of information flow.

4.2 Software Developed at University of Saskatchewan

Feed-management software was developed at the University of Saskatchewan. The feed-management software determined the rations and feed quantities needed by the pens of cattle on each day of feeding. This software had four components: feed prediction, ration management, animal body-weight prediction and data archiving. The components of the feed management software are illustrated in Figure 4.4. The code for these components is included in Appendix H. The mill computer executed the feed-management software. Figure 4.5 shows the software components installed on each of the three computers in system.

The feed-prediction component determined the quantities of feed needed by each pen for each day of feeding. Feed predictions were based upon a set of management rules programmed into the software. These management rules were based upon the rules discussed in Section 3.1.2.

The purpose of the ration-management component was to ensure that each ration was fed for the correct amount of time. For example, if step-up rations were being fed, each ration would be fed for three days, as discussed in Section 3.1.1.

The animal weight-prediction component operated in conjunction with the feed-prediction component. Knowledge of animal body weight was necessary for determining DMI/BW, which affected the magnitude and frequency of increases to feed quantities when step-up rations were fed.

The data-archiving component archived the data needed to create the feed intake history of each pen of cattle.

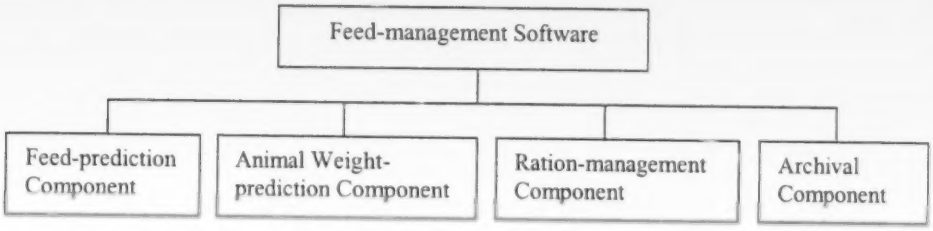


Figure 4.4 Components of the feed-management software

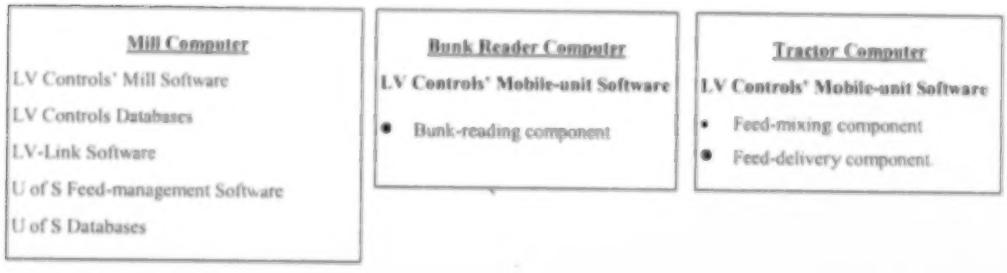


Figure 4.5: Software components of the entire system.

4.3 System Databases

A database, called the predictive database, was included in the LV Controls' system. The predictive database had two purposes. First, it contained tables of information that were needed for the feed-management and mill software to operate. Secondly, the predictive database allowed the feed-management software (Appendix H) to be integrated with the LV Control's system. Feed and ration predictions generated by the feed-management software were written into the predictive database in a format that made them compatible with the LV Controls system.

Several tables were modified to contain additional parameters needed by the feed-management software. Several new tables were added to the LV Controls' system to contain information needed by the feed-management software. The following sections describe the information contained in these tables.

4.3.1 Pen Inventory Table

The pen inventory table (tbl_Pen_Call) contained information generated by the feed-prediction software on each day of feeding. The feed-prediction software determined the quantity of feed required by each pen (Daily_Feed) and wrote these into the pen inventory table. The ration-management component determined what rations were needed by the pens (Ration_ID) and wrote these into the table.

The pen inventory table also contained parameters required by the weight-prediction component. These were the average starting weights of the animals in each pen (Starting_Weight), the estimated finishing weights of the animals in the pens (Finish_Weight) and the shrunk weight of the reference animal (SRW) of the animals in each pen. The pen inventory table also contained the predicted average body-weight of the animals in each (Current_Weight).

The pen inventory contained information that was recorded with the bunk reader computer and sent to the mill computer. These information consisted of the number of animals in each pen (Number_of_Head) and the quantity of residual feed present at each pen at the time of bunk reading (Residual). The feed-management software required these information for the feed and ration predictions made for the current day.

Table 4.1 lists the information contained in the pen inventory table. Fields names in italics indicate fields added to the original LV Controls table.

Table 4.1: Information contained in the Pen Inventory Table.

Field	Description
Pen_Number	Pen identification
Pen_Order	Order in which the pen is fed.
Number_of_Head	Number of animals in the pen.
Ration_ID	Predicted ration for the pen, identified by Ration_ID number.
Truck_ID	Identifies the truck that will feed the pen. (not used)
Daily_Feed	Total quantity of feed predicted for the pen.
Residual	Residual feed present at the time of bunk reading.
Current_Weight	Current predicted average weight of the animals in the pen.
Starting_Weight	Average weight of the animals in the pen at the start of feeding of the feeding period.
Finish_Weight	Estimated average weight of the animals in the pen at the time of finishing.
SRW	Shrunk weight of reference animals for the pen.

4.3.2 Feed Commodities Table

The feed commodity table (COMMODITY) contained a listing of the feed commodities used at the feedlot. A unique identification number identified each feed commodity (Commodity_ID). This table was modified to include the ME and DM concentrations of each feed commodity. These were needed to determine the DM and ME concentrations of the load(s) delivered to each pen. Knowledge of load DM and ME concentrations were required by the weight-prediction and feed-prediction components. Table 4.2 lists the information contained in the feed commodities table. Fields names in bold indicate new fields added to the original LV Controls table.

Table 4.2: Information contained in the commodity table.

Field	Description
Commodity_ID	Unique numeric identification number of the commodity.
Commodity Description	A description of the commodity.
ME	ME concentration of the commodity (Mcal kgDM-1)
DM	Dry-matter percentage of the commodity.

4.3.3 Ration Table

The ration table (RATION) contained a listing of the rations used at the feedlot. Unique identification numbers identified each ration (Ration_ID). Descriptions of the rations were contained in this table. These descriptions were included for the benefit of the users, so that they could identify rations by their names (Ration_Name) or by their abbreviated names (Ration).

This table was modified to include parameters needed by the feed-management software. These parameters were the order in which the rations were fed (Ration_Order) and the number of days each ration was fed (Days_On_Ration). Table 4.3 lists the information contained in the ration table. Fields names in bold indicate fields added to the original LV Controls table.

Table 4.3: Information contained in the ration table.

Field Name	Description
Ration_ID	Unique numeric identification number of the ration
Ration_Name	Name of the ration.
Ration	Abbreviated name of the ration.
Ration_Order	Order that the ration was fed.
Days_On_Ration	Number of days the ration was fed.

4.3.4 Ration Ingredient Table

The ration ingredient table (RATION_INGREDIENT) contained a listing of the feed commodities that composed each ration, identified by their respective Commodity_IDs, on an as-fed percentage basis. Table 4.4 lists the information contained in the ration ingredient table. These information were needed by the mill software when it determined the quantities of feed commodities needed in the loads of feed.

Table 4.4: Information contained in the ration ingredient table.

Field Name	Description
Ration_ID	Unique numeric identification number of the ration.
Commodity_ID	Unique numeric identification number of the commodity.
As_Fed_Per	Quantity of ingredient in ration (As-fed percentage)

4.3.5 Load Archive Table

The load archive table (tbl_ArcCommodity) was added to the predictive database. It contained a listing of the loads that were mixed and the feed commodities within them. Each load was identified by a unique numeric identifier (Load_ID). Each feed commodity was identified by its Commodity_ID.

The quantities of each feed commodity that were supposed to be in the load were also recorded (Planned_Load). The quantities of each feed commodity that were actually used in the load (Actual_Load) were recorded as well.

The load archive table was necessary because the proportions of feed commodities in a load could differ from the proportions that were specified in the ration ingredient table. Loading an incorrect quantity of a feed commodity into a load would cause the proportions to be different. Substituting one feed commodity for another that had run out, would also cause the proportions to be different. Thus, the load archive table allowed the DM and ME concentrations of each load to be determined using the exact proportions of feed commodities that were present in the load. Table 4.5 lists the information contained in the load archive table.

Table 4.5: Information contained within the load archive table.

Field Name	Description
Load_ID	Unique identification number of the load of feed.
Commodity_ID	Unique numeric identification number of the commodity.
Planned_Load	The quantity of feed needed in the load.
Actual_Load	The quantity of feed actually used in the load.

4.3.6 Archival Table

The archival table (tbl_Archive) was added to the predictive database. It recorded the data that were used to determine the feed-intake histories of the pens. Table 4.6 lists the information contained in the archival table.

Table 4.6: Information contained in the archival table.

Field Name	Description
Date	Date of feeding.
Pen_Number	Unique identification for the pen.
Mass_Residual	Mass of residual feed for the pen (pounds).
Ration_ID	Unique numeric identification number of the ration.
Number_of_Head	Number of animals in the pen.
$Cover_n$_Call*	Predicted feed quantity for the pen for cover n.*
$Cover_n$_As_Fed*	Quantity of feed actually delivered to the pen on cover n.*
$Cover_n$_Load_ID*	The load_ID of the load that was delivered to the pen on cover n.*

*Where $n = n^{th}$ feeding, if feeding n times per day.

4.3.7 Mill Tables

The predictive database contained three tables that were used by the mill software. The first table, called the load pen details table (tbl_Load_Pen_Details), contained the data that was recorded with the tractor computer and sent to the mill computer. These data consisted of the actual quantities of feed delivered to the pens on the current feeding day (AF_Actual) and the quantity of feed that was supposed to be fed to the pens (AF_Load). Table 4.7 lists that data contained in the load pen details table.

Table 4.7: Information contained in the load pen details table.

Field Name	Description
Load_ID	Unique identification number for the load of feed.
Pen_Number	The pen number of each pen that received feed from the load.
AF_Load	The quantity of feed needed in the load.
AF_Actual	The quantity of feed actually used in the load.

The second table, the load commodity table (tbl_Load_Commodity), contained a listing of the feed loads that needed to be mixed (identified by Load_ID) and the quantities of the feed commodities required in the loads (identified by Commodity_ID). This information was used by the tractor operator to determine the quantities of feed commodities needed in the loads when loads of feed were mixed. Table 4.8 lists the data contained in this table.

Table 4.8: Information contained in the load commodity table.

Field Name	Description
Load_ID	Unique identification number for the load of feed.
Commodity_ID	Commodity_ID of each feed commodity used in the load.
AF_Load	The quantity of the feed commodity used in the load.
AF_Actual	The quantity of the feed commodity needed in the load.

The third table, called the load sheet (tbl_Load_Sheet), was used to coordinate the timing of feed deliveries when feed was delivered to the pens more that once per day. It was used to determine which loads were needed in each cover. A cover was a feed delivery to a pen. For example, if a pen were fed twice daily, the first delivery would occur in the first cover and the second delivery during the second cover. Table 4.9 lists the information contained in the load sheet table.

Table 4.9: Information contained in the load sheet table.

Field Name	Description

Load_ID	Unique identification number for the load of feed.
Ration_ID	Ration type of the load.
Cover	Cover number in which the load identified by load_ID was delivered.

4.3.8 DMI/BW Settings Table

The DMI/BW settings table (tbl_DMIBW_settings) contained the DMI/BW parameters used by the feed-prediction software. These parameters defined how often feed increases could occur (determined by Rest_Days) and how large feed increases could be (Increase). Table 4.10 shows the data contained in the DMI/BW Table.

Table 4.10: Information contained in the DMI/BW settings table.

Field Name	Description
DMI_BW	DMI/BW range (%).
Increase	Size of allowed feed increase (%) for the DMI/BW range.
Rest_days	Number of rest days for the DMI/BW range.

4.3.9 System Table

The system table (tbl_System) contained parameters required for the operation of the mill and feed-management software. These parameters were the number of times the cattle were fed per day (Daily_Covers), the feed-holding capacity of the feed wagon (Max_Truck_Weight) and the number of feed delivery vehicles (Number_Of_Trucks). It was modified to include the minimum and maximum desired residual amounts that were needed by the feed management software, which were Min_Residual and Max_Residual, respectively. Table 4.11 lists these parameters. Fields names in bold indicate fields added to the original LV Controls table.

Table 4.11: Information contained in the system table.

Variable Name	Description
Daily_Covers	Number of feedings per day.
Max_Residual	Maximum desired residual (pounds).
Min_Residual	Minimum desired residual (pounds).
Max_Truck_Weight	Feed holding capacity of the truck(s) (pounds).
Number_of_Trucks	Number of feed trucks.

5. FEED-MANAGEMENT SOFTWARE

5.1 ME and DM Concentrations

This section describes the calculations that were required for determining the ME and DM concentrations of the loads of feed. These calculations were needed by the weight-prediction and feed-prediction components of the feed-management software. The weight-prediction component required the DM and the ME concentrations of the feed in order to determine the animal weight gains. The feed delivered to a pen was made up of several loads. Each load was made up of several commodities. Each feed commodity had its own ME and DM concentration. The quantities of feed commodities in each load determined the ME and DM concentration of the load. The quantities of the loads delivered to the pen, and their respective ME concentration and DM concentration, determined the ME and DM concentrations of the total feed delivered to the pen. Figure 5.1 illustrates the relationships between feed commodities, feed loads and the total feed delivered to the pen.

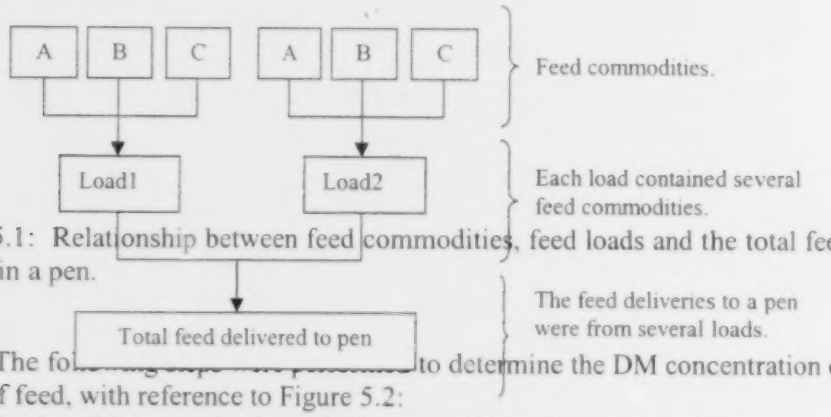


Figure 5.1: Relationship between feed commodities, feed loads and the total feed present in a pen.

The following steps were performed to determine the DM concentration of a load of feed, with reference to Figure 5.2:

1. The load archive contained the feed commodities that were used in the load (identified by Commodity_ID) and the quantity of each feed commodity used in the load (AF_Actual).
2. For each feed commodity in the load, the corresponding records from the commodity table were retrieved using their Commodity_IDs as the index.
3. These records contained the DM concentrations of the feed commodities used in the load. The DM concentration of the j^{th} load delivered to the pen ($loadDMc_j$) was calculated according to the following formula:

$$loadDMc_j = \frac{\sum(CommodityAF_i)(CommodityDMc_i)}{\sum CommodityAF_i}, \qquad (5.1)$$

where:

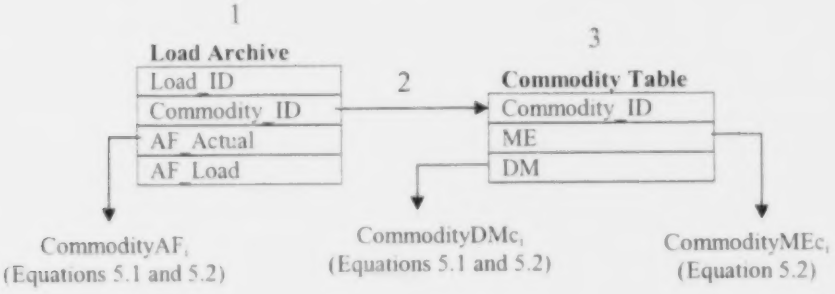
$CommodityAF_i$ = as fed quantity of the i^{th} feed commodity in the load (kgAF) and $CommodityDMc_i$ = dry matter concentration (kgDM $kgAF^{-1}$) of the i^{th} feed commodity.

With reference to Figure 5.2, the following steps were performed to calculate the ME concentration of a load:

1. The load archive contained the feed commodities that were used in the load (identified by Commodity_ID) and the quantity of each feed commodity used in the load (AF_Actual).
2. For each feed commodity in the load, the corresponding records from the commodity table were retrieved using their Commodity_IDs as the index.
3. These records contained the ME concentrations of the feed commodities used in the load. The ME concentration of the j^{th} load delivered to the pen ($loadDMc_j$) was calculated according to the following formula:

The ME concentration of the j^{th} load delivered to the pen was calculated according to the following formula:

$$loadMEc_j = \frac{\sum (CommodityAF_i)(CommodityDMc_i)(CommodityMEc_i)}{\sum (CommodityAF_i)(CommodityDMc_i)}, \quad (5.2)$$



where:
$CommodityMEc_i$ = ME concentration of the i^{th} commodity (Mcal $kgDM^{-1}$).

Figure 5.2: Data source tables for determining the ME and DM concentrations of feed batches.

The quantity of feed dry matter in the feed delivered to a pen on day_n was calculated using:

$$FeedDM_n = \frac{\sum (LoadAF_j)(LoadDMc_j)}{NumHead_n}, \quad (5.3)$$

where:
$LoadAF_j$ = the quantity of feed from the j^{th} load delivered to the pen and
$NumHead_n$ = number of animals in the pen on day_n.

The ME concentration of the feed delivered to a pen depended upon the number of loads of feed delivered to the pen and their respective amounts. The ME concentration of the feed delivered to a pen was calculated using:

$$FeedMEc_n = \frac{\sum (LoadAF_j)(LoadDMc_j)(LoadMEc_j)}{\sum (LoadAF_j)(LoadDMc_j)}$$

(5.4)

The ME concentration of the total feed in the pen was different from the ME concentration of the feed delivered to the pen. This was because the total feed in the pen included the residual feed. The residual feed was from the feed delivered to the pen one day earlier. The ME and DM concentrations of the residual feed on day_n were assumed to be the same as the feed delivered on day_{n-1}. This is illustrated in Figure 5.3. This assumption was made for ease of calculation. Also, since residual quantities were estimated, it did not make sense to expend a great deal of effort calculating the exact DM and ME concentrations of the residual feed. Furthermore, the magnitudes of the expected residual feed quantities were expected to be smaller than the magnitudes of the feed deliveries, it was expected that the magnitude of error caused by this assumption would be minimal.

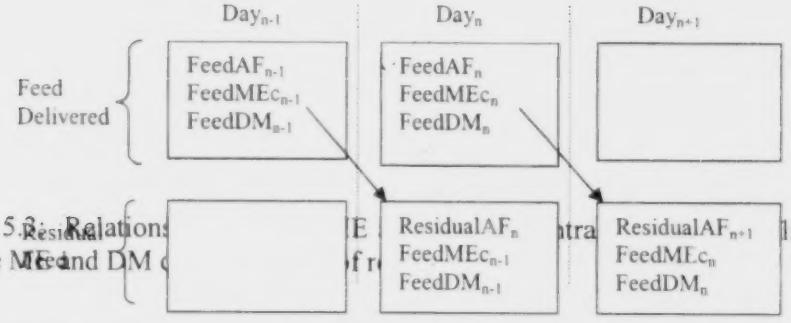


Figure 5.3: Relations[illegible] liveries and the ME and DM c[illegible] f r[illegible]

The ME concentration of the total feed present in the pen on day_n was calculated in the following manner:

$$PenME_n = \frac{(ResidualDM_n)(FeedMEc_{n-1}) + (FeedDM_n)(FeedMEc_n)}{ResidualDM_n + FeedDM_n} \qquad (5.5)$$

where:

$ResidualDM_n$ = quantity of residual dry matter in the bunk (kgDM head^{-1})

The quantity of residual feed dry matter in the bunk on day_n, with units of kgDM per head, was calculated as follows:

$$ResidualDM_n = \frac{(ResidualAF_n)(FeedDMc_{n-1})}{NumHead_{n-1}}, \qquad (5.6)$$

where:

$ResidualAF_n$ = the quantity of residual present in the bunk on day_n (kgAF) and

$NumHead_{n-1}$ = the number of animals in the pen on day_{n-1}.

5.2 Dry-matter Intake

The dry matter intake of a pen, on day_n, was calculated using the following formula:

$$PenDMI_n = FeedDM_n + ResidualDM_n - ResidualDM_{n+1}. \qquad (5.7)$$

The feed intake of a pen cannot be determined until the residual feed remaining on the next day ($ResdidualDM_{n+1}$) can be determined. This is illustrated in Figure 5.4

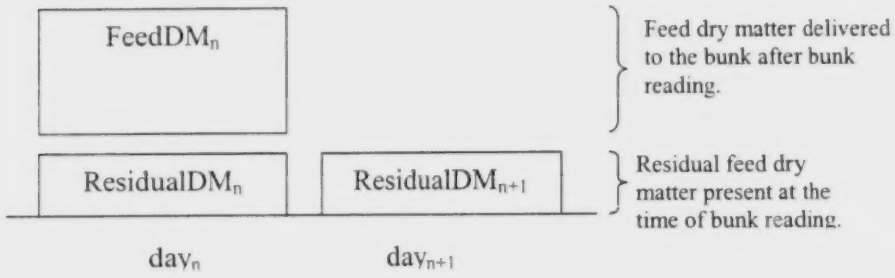


Figure 5.4: Illustration of the feed components needed to determine dry matter intake.

5.3. Feed-Prediction Software

The feed-prediction software determined the quantity of feed needed by the cattle on each feeding. It determined whether the quantity of feed delivered to each pen should be increased, decreased or maintained at the same level, relative to the quantity of feed delivered on the previous day. Decisions to increase, decrease, or maintain the quantity of feed predicted for a pen depended upon the quantity of feed left in the bunk at 0800 h, called the residual feed.

5.3.1 Quantifying Residual Feed

In the version of the feed-prediction software used during the early feeding test (EF) (September 2001), a 10-point bunk scoring system was used to quantify the residual feed present in the bunks prior to feeding. The quantity of residual feed was expressed as a percentage of the feed delivered to the pen on the previous day. This was translated into a bunk score using Table 5.1. The actual percentage of the residual used in subsequent calculations was the midpoint of the range in shown in Table 5.1.

In this version of the feed-prediction software, a bunk score of 0 indicated that the bunk was empty. Feed quantities might need to be increased. A bunk score equal to 1 indicated that the quantity of feed delivered to the cattle on the previous day matched their appetites. The feed quantity delivered on the current day should remain the same. Bunk scores greater than 1 meant that the cattle were unable to consume the quantity of feed delivered to them on the previous day. Feed quantities should be reduced.

Table 5.1: Bunk score settings used by the feed-prediction software.

Bunk Score	Residual Feed* (%)	Bunk Score	Residual Feed* (%)
0	0	5	30-40

1	0-5	6	40-50
2	5-10	7	50-60
3	10-20	8	60-80
4	20-30	9	80-100

*Percentage of previous day's feed remaining at 0800 h.

The bunk scoring system was impractical because it required the user to translate the residual feed into a bunk score before it was recorded. In the second version of the software, used during the late feeding test (LF) (April 2002), the bunk scoring system was removed. In this version of the software, the bunk reader recorded the mass of residual feed (in pounds), using the bunk reader computer, and this quantity was used in subsequent calculations.

In this version of the feed-prediction software, the limits of acceptable residual (bunk score of 1) were defined as fixed quantities. A lower acceptable limit of 10 pounds and an upper limit of 20 pounds were suggested by the feedlot staff. The size of the minimum and maximum allowed residual quantities will vary depending upon the size of pens used. If this software is used for different sized pens, feedlot personnel who are familiar with the feeding of such pens should be consulted to determine the allowable residual sizes.

5.3.2 Determining Feed Quantities

The operation of the feed-prediction software is summarized as follows, with reference to Figure 5.5.

1. When the residual was within the limits defined by the minimum and maximum allowable amounts (bunk score of 1), the amount of feed delivered to the pen was held at the same level as the previous day's feed delivery.
2. When the residual was less than the minimum allowable amount (bunk score of 0), the software increased the amount of feed that was delivered, relative to the previous day's delivery, if no other increases had occurred within the specified number of rest Days and a ration change was not scheduled. If there were increases in feed in the specified number of rest days, or a ration change was scheduled, the amount of feed delivered to the pen was held at the same level as the previous day's feed delivery.
3. When the residual was greater than the maximum allowable amount (bunk score greater than 2), the software decreased the amount of feed that was delivered relative to the previous day's delivery.

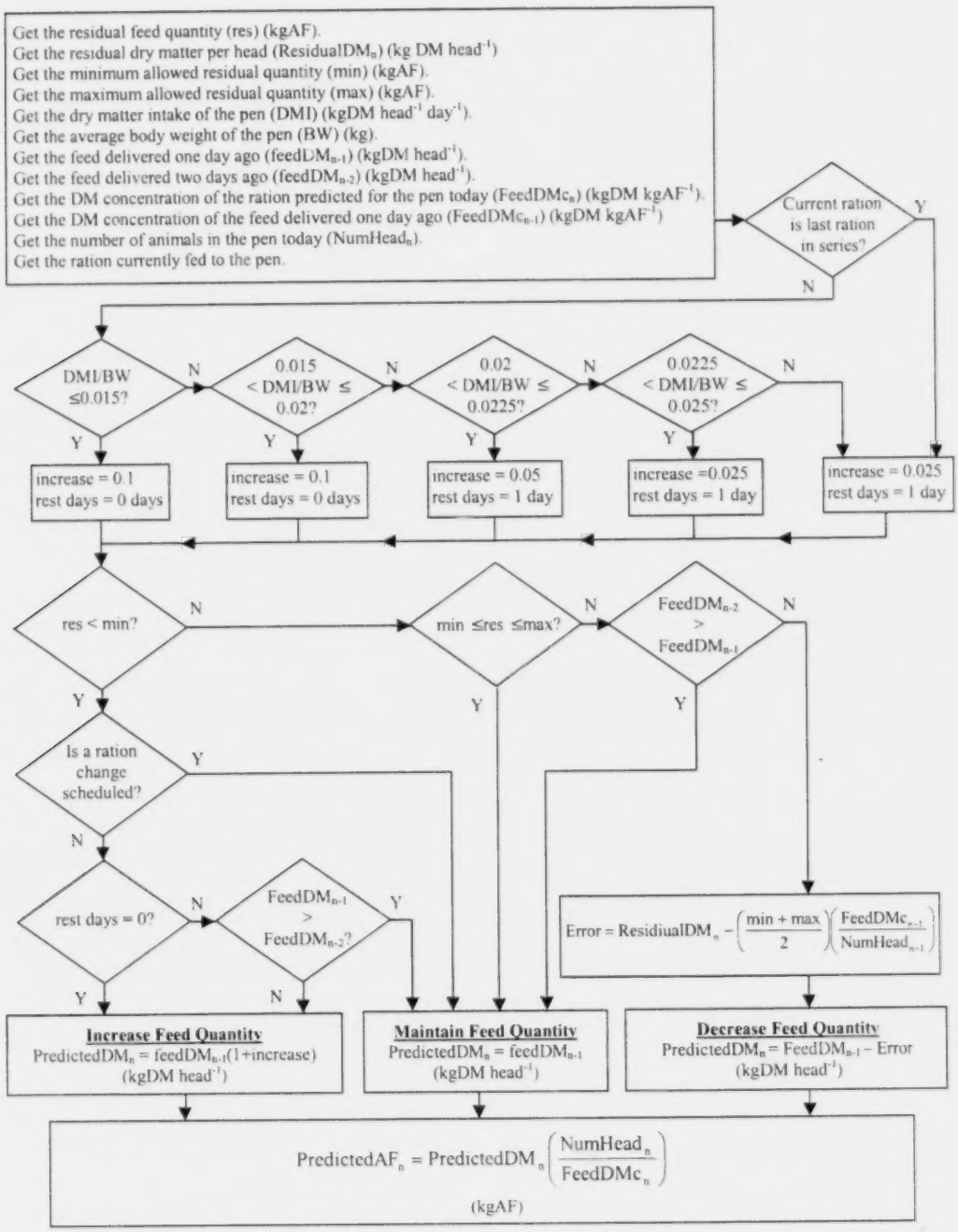

Get the residual feed quantity (res) (kgAF).
Get the residual dry matter per head (ResidualDM$_n$) (kg DM head^{-1})
Get the minimum allowed residual quantity (min) (kgAF).
Get the maximum allowed residual quantity (max) (kgAF).
Get the dry matter intake of the pen (DMI) (kgDM head^{-1} day^{-1}).
Get the average body weight of the pen (BW) (kg).
Get the feed delivered one day ago (feedDM$_{n-1}$) (kgDM head^{-1}).
Get the feed delivered two days ago (feedDM$_{n-2}$) (kgDM head^{-1}).
Get the DM concentration of the ration predicted for the pen today (FeedDMc$_n$) (kgDM kgAF^{-1}).
Get the DM concentration of the feed delivered one day ago (FeedDMc$_{n-1}$) (kgDM kgAF^{-1})
Get the number of animals in the pen today (NumHead$_n$).
Get the ration currently fed to the pen.
Current ration is last ration in series?
DMI/BW ≤0.015?
0.015 < DMI/BW ≤ 0.02?
0.02 < DMI/BW ≤ 0.0225?
0.0225 < DMI/BW ≤ 0.025?
increase = 0.1 rest days = 0 days
increase = 0.1 rest days = 0 days
increase = 0.05 rest days = 1 day
increase =0.025 rest days = 1 day
increase = 0.025 rest days = 1 day
res < min?
min ≤res ≤max?
FeedDM$_{n-2}$ > FeedDM$_{n-1}$
Is a ration change scheduled?
rest days = 0?
FeedDM$_{n-1}$ > FeedDM$_{n-2}$?
Error = ResidiualDM$_n$ − ((min + max)/2)(FeedDMc$_{n-1}$/NumHead$_{n-1}$)
Increase Feed Quantity
PredictedDM$_n$ = feedDM$_{n-1}$(1+increase) (kgDM head^{-1})
Maintain Feed Quantity
PredictedDM$_n$ = feedDM$_{n-1}$ (kgDM head^{-1})
Decrease Feed Quantity
PredictedDM$_n$ = FeedDM$_{n-1}$ − Error (kgDM head^{-1})
PredictedAF$_n$ = PredictedDM$_n$(NumHead$_n$/FeedDMc$_n$)
(kgAF)

Figure 5.5: Flowchart of the process for determining feed quantities.

Maintaining Feed Quantities

When the residual was within the limits defined by the minimum and maximum allowable quantities (a bunk score of 1 in the first version of the software), the quantity of feed predicted for the pen was held at the same level as the previous day's feed delivery. The quantity of feed dry-matter predicted for the current day was calculated using:

$$\text{PredictedDM}_n = \text{FeedDM}_{n-1}. \quad (5.8)$$

where:

FeedDM_{n-1} = previous day's feed dry matter delivered (kgDM head-^{1}).

Increasing Feed Quantities

When step-up rations were fed, the size and frequency of increases to predicted feed quantities were determined using a management parameter called the dry-matter intake: body weight ratio (DMI/BW). The DMI/BW was the quotient of the pen's average dry-matter intake and the average body-weight of the animals in the pen.

Five ranges of DMI/BW were used in this project. For each range, the size of feed increase was determined by the Increase parameter. The rest days parameter determined the number of days that had to elapse between consecutive feed increases. For example, a rest days setting of 1 indicated that one day had to elapse between consecutive feed increases. In other words, feed increases were not allowed on consecutive days. A rest rays setting of 0 meant that feed increases could occur on consecutive days. The concept of rest days is illustrated in Figure 5.6. The DMI/BW ranges used for this project, and their respective Increase and rest days p-arameters are listed in Table 5.2.

When the pens were finished their step-up rations and were on their final high-grain finishing ration, increases and rest days were limited to those specified by DMI/BW > 2.5%.

Table 5.2: Dry-matter intake: body-weight parameters.

DMI/BW	Increase* (%)	Rest Days**
0 to 1.5	10	0
1.5 to 2.0	10	0
2.0 to 2.25	5	1
2.25 to 2.50	5	1
> 2.5	2.5	1

*Size of dry-matter increases, relative to previous day's feed dry matter delivered.

**Number of days that must elapse between subsequent feed increases.

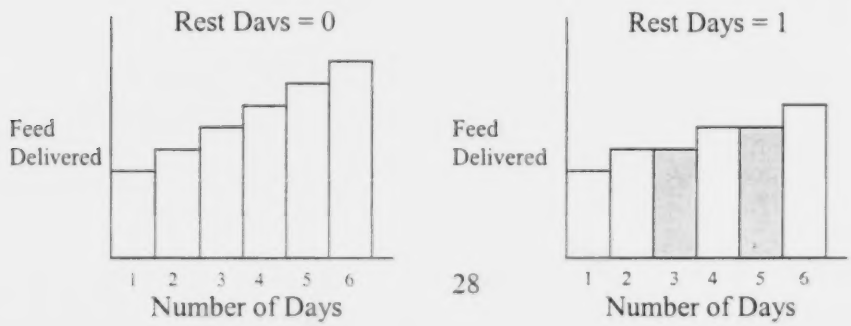


Figure 5.6: Illustration of rest days between feed increases.

When the quantity of residual was less than the minimum desired quantity (a bunk score of 0 in the first version software), the feed-prediction software increased the quantity of feed that was delivered, relative to the previous day's delivery, if the following two conditions were met:

1. if no other increases had occurred within the specified number of rest days and
2. a ration change was not scheduled for the current feeding.

When these conditions were met, the feed dry-matter was increased according to the following formula:

$$\text{PredictedDM}_n = \text{FeedDM}_{n-1}\left(1+\frac{\text{Increase}}{100}\right), \tag{5.9}$$

where:

Increase = percentage increase parameter for current DMI/BW.

If there were increases in feed quantities within the specified number of rest days, or a ration change was scheduled for the current feeding, the quantity of feed delivered to the pen was held at the same level as the previous day's feed delivery (Equation 5.8).

The feed-prediction software determined if there had been feed increases by comparing the feed delivered to the pen on day_{n-2} ($FeedDM_{n-2}$) to the feed delivered on day_{n-1} ($FeedDM_{n-1}$). If $FeedDM_{n-1}$ was greater than $FeedDM_{n-2}$ an increase in feed quantity had occurred.

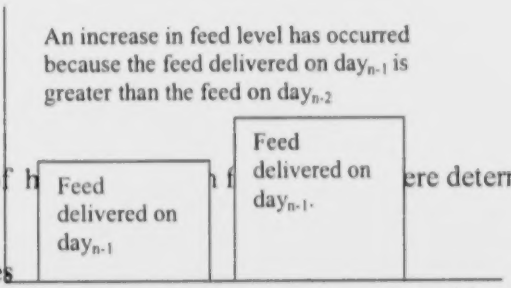

An increase in feed level has occurred because the feed delivered on day$_{n-1}$ is greater than the feed on day$_{n-2}$
Feed Delivered
Feed delivered on day$_{n-1}$
Feed delivered on day$_{n-1}$.

Figure 5.7: Illustration of h f ere determined.

Decreasing Feed Quantities

When the residual was greater than the maximum allowable quantity (a bunk score of 2 or greater in the first version of the feed-prediction software) the software decreased the quantity of feed that was predicted for the pen, relative to the quantity delivered on the previous day.

In the version of the software used in the EF test, the quantity of feed delivered was reduced by a quantity equal to 133% of the residual feed. This value was chosen because it was believed that this would reduce the total feed delivered to the bunk, forcing the animals to consume the feed left in the bunk. The formula for calculating the required quantity of feed was:

$$\text{PredictedDM}_n = \text{FeedDM}_{n-1} - \text{ResidualDM}_n(1.33). \tag{5.10}$$

In this version of the software, feed levels were reduced on each day residuals were too large. However, it was observed in later testing, that this caused the predicted feed quantities to be reduced too rapidly. When the cattle

increased their appetites, the feed-prediction software had reduced feed quantities too greatly and it was unable to increase the feed quantities at a rate fast enough to match the appetites of the cattle. This resulted in the occurrence of empty bunks (too little residual feed) and was a concern because it meant that the cattle might have not received sufficient feed during that time.

The version of the software used in the LF test was modified so that it would reduce feed quantities at a lesser rate. The software was modified so that it did not reduce feed quantities on consecutive days. On the first day that residuals were too large, the quantity of feed delivered to the cattle was reduced. On the second day, if residuals were still too large, the quantity of feed delivered to the cattle was kept at the same quantity as from the first day. On the third day, if residuals were still too large, the quantity of feed delivered to the cattle was reduced relative to the quantity delivered on the second day.

The feed-prediction software determined if feed quantities had been reduced comparing the feed deliveries made on day_{n-1} to those made on day_{n-2}. When the feed delivered on day_{n-1} was less than that delivered on day_{n-2}, a decrease in feed quantity had occurred. This indicated that a decrease in feed quantity had already occurred and the quantity of feed predicted for the current feeding should not be further reduced, relative to the quantity predicted for day_{n-1}.

In the version of the software used in the LF test, the quantity of feed predicted was reduced by calculating the error, which was the difference between the quantity of residual feed present in the bunk and the average of the upper and lower desired residual limits (values of pounds). The average of the specified limits represented the target value for the quantity of desired residual feed. The error was calculated as:

$$\text{Error} = \text{ResidiualDM}_n - \left(\frac{\text{min} + \text{max}}{2}\right)\left(\frac{\text{FeedDMc}_{n-i}}{\text{NumHead}_{n-1}}\right), \tag{5.11}$$

where:
min = minimum desired quantity of residual feed (kgAF) and
max = maximum desired quantity of residual feed (kgAF).

When the quantity of predicted feed needed to be reduced, it was calculated as the quantity of feed delivered to the pen on the previous day minus the error:

$$\text{PredictedDM}_n = \text{FeedDM}_{n-1} - \text{Error}. \tag{5.12}$$

5.4 Weight-Prediction Software

The weight-prediction software operated in conjunction with the feed-prediction software. Knowledge of animal body weights was necessary to determine the DMI/BW of the pens. The weight-prediction software determined the amount of weight gain that occurred for each pen, on each day of feeding. The weight gain that occurred each day was added to the initial average weight of the cattle to arrive at a daily estimated weight of the cattle in the pen.

The NRC (2000) developed a model that determined animal body-weight gain from feed and animal factors. Figure 5.7 illustrates the portions of the NRC model used for this project. The 2000 model was based on the earlier 1984 model that determined the shrunk weight gain (SWG) of cattle was:

$$SWG = 13.91RE^{0.9116}SBW^{-0.6837}, \quad (5.13)$$

where:

RE = retained energy (Mcal) and

SBW = shrunk body weight (kg).

For this project, shrunk body weights were assumed to be 97 percent of live body weights.

The NRC (2000) model for shrunk body weight gain had adjustments that took into account different breeds of cattle. These adjustments were based upon the concept that the body composition of cattle and the composition of weight gain is constant at any proportion of mature size, with maturity defined as the weight at 25% body fat (CSIRO 1990). This concept required a data set of body size and fatness for one type of animal to adjust for others (Buchanan-Smith and Fox 2000). The shrunk weight at which the standard animal achieved slaughter end was called the standard reference weight (SRW) (Buchanan-Smith and Fox 2000). The data set used by NRC (2000) was the NRC (1984) data set for medium-frame size cattle. Three SRWs were selected to correspond to different levels of fatness currently achieved by cattle in the North American market. These SRWs were 435, 462 and 478 kg.

In order to use the NRC (2000) model, the user must estimate the shrunk weight at which the cattle under consideration will achieve the same level of fatness as the reference animal (FSBW) (Buchanan-Smith and Fox 2000). These two weights establish an equivalent shrunk body weight (EQSBW), which was given by:

$$EQSBW = \frac{SRW}{FSBW}, \quad (5.14)$$

where

SRW = shrunk weight of reference animal (kg) and

FSBW = shrunk weight at which animal under consideration will achieve the same level of fatness as the reference animal.

The NRC (2000) model is thus:

$$SWG = 13.91RE^{0.9116}EQSBW^{-0.6837}, \quad (5.15)$$

where:

RE = retained energy.

The average body weight of the animals in each pen, on each day of feeding, was determined by adding the calculated weight gain (Equation 5.16) to their initial average body weight.

5.4.1 Animal Descriptors

The use of the NRC (2000) model requires the user to describe the animal so its maintenance energy requirement (NE_m), with units of Mcal, can be calculated. The maintenance energy requirement of the animal was given by:

$$NE_m = SBW^{0.75}\left[0.077(BE)(L)(SEX)(0.005(CS-1)+0.8)+.0007(20-T_p)\right], \quad (5.16)$$

where:

SBW = shrunk body-weight (kg),

BE = breed modifier,
L = lactation modifier (1.2 if lactating, 1.0 otherwise),
SEX = gender modifier (1.15 for bulls, 1.0 otherwise),
CS = animal condition score (1-9 scale) and
T_p = previous average monthly temperature (°C).

The NRC (2000) model also included adjustments for previous temperature and environmental conditions (heat and cold stress). These adjustments were not included because previous experiments conducted at the University of Saskatchewan Beef Research station indicated that these adjustments caused animal body-weight gains to be underestimated (Block et al. 2001). It was assumed that more accurate results could be obtained by not including these adjustments. Thus, when equation 5.16 was implemented, the T_p term was assumed to be 20°C.

5.4.2 Feed Descriptors

The model required the user to supply the ME (Mcal $kgDM^{-1}$) and DM (kgDM $kgAF^{-1}$) for each feed commodity that the pens of animals received. These inputs allowed the model to determine the quantity of energy in the feed available for gain (NE_{ga}) and the quantity of energy in the feed available for maintenance (NE_{ma}), both with units of Mcal $kgDM^{-1}$. These inputs are illustrated in Figure 5.8.

The energy concentration in the diet available for maintenance (NE_{ma}) was calculated in the following manner, as reported by the NRC (2000):

$$NE_{ma} = 1.37ME - 0.138ME^2 + 0.0105\ ME^3 - 1.12, \quad (5.17)$$

The energy concentration of the diet available for gain (NE_{ga}) was calculated in the following manner, as reported by the NRC (2000):

$$NE_{ga} = 1.42ME - 0.174ME^2 + 0.0122\ ME^3 - 1.65. \quad (5.18)$$

The NE_{ma} and NE_{ga} values used for the derivations of these equations were based upon comparative slaughter studies involving more than 2700 animals fed complete, mixed diets at, or near ad libitum, for 100 to 200 days (NRC 2000). The NRC (2000) notes that the data used for developing equations 5.18 and 5.19 were not uniformly distributed across the range of ME concentrations encountered in practical situations (1 percent < 1.9 Mcal kg^{-1}; 22 percent 1.9 – 2.6 Mcal kg^{-1}; 65 percent 2.6 - 2.9 Mcal kg^{-1}; 12 percent > 2.9 Mcal kg^{-1}). The NRC (2000) recommends that caution should be exercised in use of these equations for predicting NE_{ma} and NE_{ga} for values of individual feed commodities or for feeds outside the ranges indicated above. The range of NE values of the feeds used in the experiments conducted for this thesis were within the previously listed ranges.

The quantity of feed dry matter needed for maintenance (I_m), with units of kgDM, can be calculated from the animal's maintenance energy requirement and the energy density of the feed available for maintenance:

$$I_m = \frac{NE_m}{NE_{ma}}. \quad (5.19)$$

Ionophores in the diet increase NE_{ma} by 12% (NRC 2000). When ionophores are present in the diet, the NE_{ma} term in equation 5.20 should be multiplied by 1.12.

5.4.3 Dry Matter Intake and Retained Energy

The retained energy is the energy that was consumed by the animal and is available for growth. The NRC (2000) reported that RE could be determined from the DMI, I_m and the energy concentration of the feed available for gain (NE_{ga}). The RE was calculated using the following formula:

$$RE = NE_{ga}(DMI - I_m). \quad (5.20)$$

Growth occurs when RE is greater than zero and the animal has an energy surplus. This occurs when DMI was greater than I_m. When RE is less than zero, the animal has an energy deficit and it will lose body weight. It should be noted body weight losses could not be calculated with Equation 5.16 because the RE term is raised to a power of less than one. RE values less than zero will result in an imaginary number. Therefore, when RE was less than zero, it was assumed that no body-weight gain occurred.

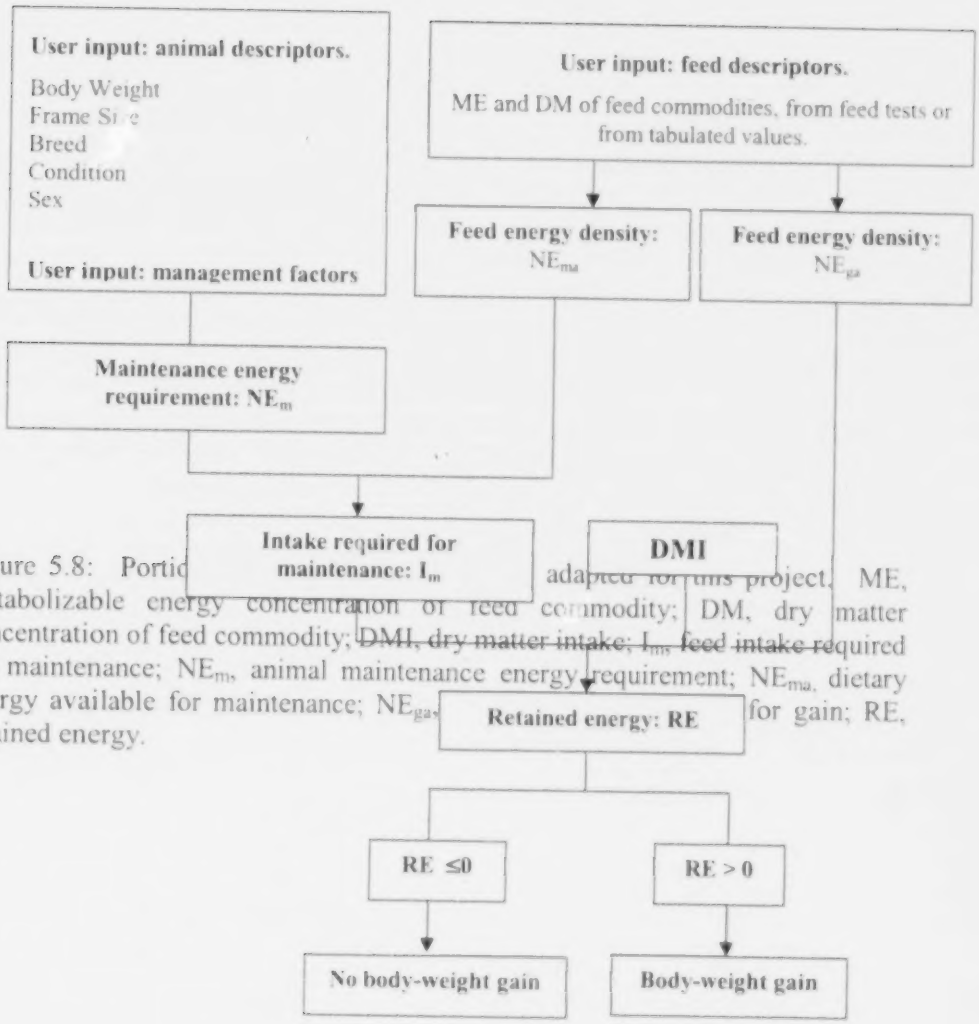


Figure 5.8: Portio adapted for this project. ME, metabolizable energy concentration of feed commodity; DM, dry matter concentration of feed commodity; DMI, dry matter intake; I_m, feed intake required for maintenance; NE_m, animal maintenance energy requirement; NE_{ma}, dietary energy available for maintenance; NE_{ga}, for gain; RE, retained energy.

5.5 Ration-Management Software

The purpose of the ration-management component was to change rations at predetermined times. In the case of step-up rations, these intervals would be set for three days. The following example illustrates how the rations were changed for a pen. In this example, the Pen_Number is 1 and the current date is day_n.

The first step was to determine which ration was fed to the pen on day_{n-1}. This was accomplished by selecting the record from the archival table whose Pen_Number = 1 and whose Date = day_{n-1}. This results in the record shown in Figure 5.9. From this figure, it is determined that Ration_ID = 57 was fed to the pen on day_{n-1}.

Date	Pen_Number	Ration_ID	
day_{n-1}	**1**	**57**	←
day_{n-2}	1	57	
day_{n-3}	1	57	
day_{n-4}	1	56	
day_{n-5}	1	56	

Figure 5.9: Dete
indicates the rec
day_{n-1}.

The arrow
nd Date =

The next step was to select all the records from the archival database whose Pen_Number = 1 and whose Ration_ID = 57. This resulted in the records shown in Figure 5.7. A software algorithm in the ration-management software counted the number of records in the archival database whose Pen_Number = 1 and whose Ration_ID = 57 and used the count as the number of days Ration_ID = 57 was fed to Pen_Number = 1. From the illustration of Figure 5.10, it was determined the Ration_ID = 57 was fed to Pen_Number = 1 for 3 days.

Date	Pen_Number	Ration_ID	
day_{n-1}	**1**	**57**	←
day_{n-2}	**1**	**57**	←
day_{n-3}	**1**	**57**	←
day_{n-4}	1	56	
day_{n-5}	1	56	

Ration_ID = 57 was fed for 3 days

Figu
reco
Pen_

ration was fed. The
chival database whose

Next, it was necessary to determine how long Ration_ID = 57 was supposed to be fed and its order in the ration series. This was accomplished by selecting the Ration_ID from the Ration table whose Ration_ID = 57. This is illustrated in Figure 5.11. From this figure, it was determined that Ration_ID = 57 was supposed to be fed for 3 days (Days_On_Ration) and it was the second ration in the ration series (Ration_Order).

Ration_ID	Days_On_Ration	Ration_Order	
56	3	1	
57	**3**	**2**	←
58	3	3	
59	3	4	

Figure 5.11: Determining the feeding time and ration order for the current ration. The record indicated by the arrow is a subset of the Ration table whose Ration_ID = 57.

Next, it was necessary to compare the desired feeding time (Days_on_Ration) to the amount of time Ration_ID = 57 had been fed. Previously, it was determined that Ration_ID=57 had been fed for 3 days. Because 3 days is equal to the desired feeding time, the ration must be advanced to the next one in the series. This is accomplished by incrementing the Ration_Order by one, resulting in Ration_Order = 3. Now it must be determined which Ration_ID has a Ration_Order = 3. This was accomplished by selecting the record from the ration table that had a Ration_Order = 3. It can be seen from Figure 5.9 that the Ration_ID = 58 has a Ration_Order = 3. This is the ration that will be fed to the pen on day_n. This is illustrated in figure 5.12.

Ration_ID	Days_On_Ration	Ration_Order	
56	3	1	
57	3	2	
58	**3**	**3**	←
59	3	4	
60	3	5	

Figure 5.12: Det… he record indicated by the a… r = 3.

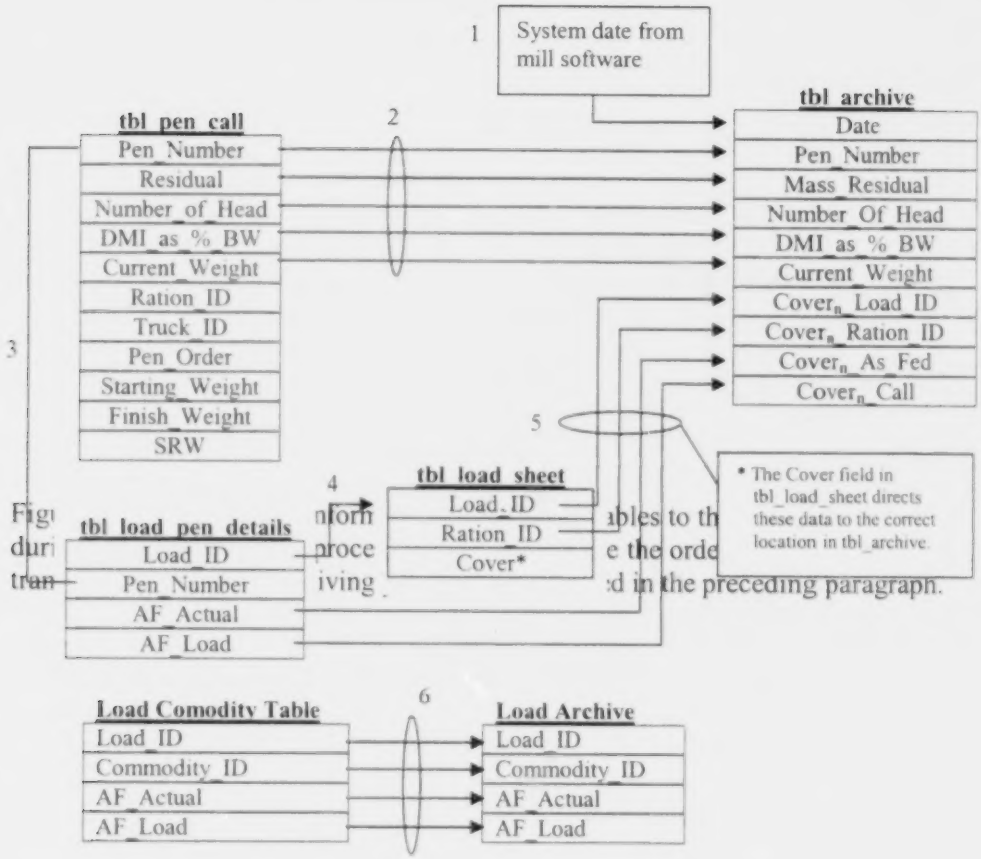
This process will continue until the last ration in the ration series is reached. At that point, the ration will no longer be advanced to the next ration in the series because it is the last one in the series. In the following example, once Pen_Number = 1 advances to Ration_ID = 60, no further advancements in the ration series will be made because there are no more rations in the series. It should be noted that the Ration_IDs could not be used to determine the order of the rations in the ration series. Because of the manner in which Ration_IDs were assigned, they might not be sequential.

5.6. Archival Software

The data-archiving component archived the data necessary to create the feed intake history of the pens. Data were archived after the feeding of the pens was completed on each day of feeding.

The archiving of data is explained with the aid of Figure 5.13. The first step was to copy the system date into the archival table (1). Next, data were copied directly from the pen inventory table into the archival table (2). These data were the pen numbers, residuals for each pen, the number of animals in each

pen, and the DMI/BW of each pen. Next, the load pen details table was checked to see what loads were delivered to that pen (3). For each load in the load pen details table, the corresponding entry in the load sheet table was located (4). The cover field in the load sheet table was used as an index to place the data the load sheet and load pen details tables into the correct locations in the archival table (5). Finally, information in the load commodities table was copied directly into the load archive table (6).



Figu nform ables to th
duri proce e the orde
tran iving d in the preceding paragraph.

6. SYSTEM TESTING

6.1 Preliminary Tests

Preliminary tests were conducted to ensure that the ration-management portion of the software was able to change rations at the specified three-day intervals.

6.2 Early Feeding Test

The purpose of the early feeding test (EF) was to evaluate the feed-prediction and animal body weight prediction capabilities of the software. This test was conducted from November 7, 2001 until November 27, 2001, with 270 Charolais cross calves. The calves were grouped into twenty pens with ten pens containing 13 animals per pen and ten containing 14 animals per pen.

The feed-prediction software was used to predict the feed quantities needed by the pens of cattle. The feedlot staff were consulted to ensure the feed predictions were reasonable. When they had objections about the computer-predicted values, their feed predictions were used in place of the computer-predicted values.

The animals were fed a ration that consisted of 40% barley silage, 25% hay, 27% barley grain and 8% supplement pellets, on an as-fed basis. Feeding occurred once per day in the morning. The pens were bedded with straw on November 8, 16, 23 and 27. Table 6.1 lists the average body weights of the animals in each pen at the beginning of the EF test.

The weights of the animals were recorded when they arrived at the feedlot on November 2, 2001. These weights were used to determine the average weights of the animals in each pen. The animals were weighed on November 27 and again on November 28. The body weights on these days were averaged and used to determine the average body weight of the animals in each pen for November 27.

Table 6.1: Average animal body weights for each pen at the beginning of the early feeding test.

Pen	Average Starting Weight* (kg)	SD (kg)	Pen	Average Starting Weight* (kg)	SD (kg)
3	246.8	12.3	14	262.8	12.4
4	255.1	18.8	15	266.5	9.3
5	247.7	12.6	16	263.0	11.4
6	263.3	10.9	17	270.0	12.9
7	265.0	19.4	18	264.6	21.3
8	259.5	17.4	19	268.9	11.5
9	262.0	16.9	20	259.6	17.9
10	265.2	15.0	21	264.0	14.3
11	259.4	18.5	22	256.9	22.1

12	260.2	10.0	23	253.0	9.1

*Values are shrunk weights.

It should be noted that the animals were weighed five days before the commencement of this experiment. Thus, five days of body weight gain were not accounted for. Also, the animals had been through a sale and shipping prior to arrival at the feedlot, so they did not have access to feed and water during this time. This may have caused their body weights to decrease (i.e. body weight shrink). The experiment was commenced five days after they arrived at the feedlot to give the calves time to adjust to the feed and develop a consistent feed intake. The feed-prediction software was written with the assumption that the cattle consumed feed on each day and would not have functioned properly if the cattle had zero feed intake on a given day.

The tractor computer was used to record the quantities of feed commodities used in the loads of feed and the quantity of feed delivered to the bunks. The bunk reader computer was used to record bunk residuals. The mill computer was used to generate and archive the feed predictions and the data recorded with the tractor and bunk reader computers.

The bunk scoring system that expressed the bunk residuals as a percentage of the previous day's feed was used in this test, as previously discussed in Section 5.3.1. The bunk score settings used for this experiment are listed in Table 6.2. During this test, the bunk score of 1 was adjusted to improve the stability of the feed-prediction software because it was observed that the feed-prediction software tended to reduce feed-predictions too frequently. These adjustments are listed in Table 6.3.

Table 6.2: Bunk score settings used in the early feeding test.

Bunk Score	Residual* (%)	Bunk Score	Residual* (%)
0	0	5	30-10
1	0-5	6	40-50
2	10-15	7	50-70
3	15-20	8	70-90
4	20-30	9	90-100

*Percentage of previous day's feed delivery remaining at 0800 h.

Table 6.3: Adjustments to bunk score settings in the early feeding test.

Bunk Score*	Date		
	10/07/01 - 10/17/01	10/18/01 - 10/21/01	10/21/01 - 10/24/01
0	0%	0-2.5%	0-5%
1	0-5%	2.5-10%	5-10%

*Bunk scores greater than 1 were not adjusted.

The DMI/BW settings for this experiment are listed in Table 6.4 and Table 6.5 lists the variables that were used in the weight prediction equation for this test.

Table 6.4: DMI/BW settings used in the early feeding test.

DMI/BW (%)	Increase* (%)	Rest Days**
0 to 1.5	10	0
1.5 to 2.0	10	0
2.0 to 2.25	5	1
>2.5	2.5	1

*Size of daily feed dry matter increase, relative to previous day's feed dry matter delivered.

**Number of days that had to elapse between consecutive feed dry matter increases.

Table 6.5: Weight prediction variables used in early feeding test.

Variable	Value
Final shrunk body weight (FSBW)	625 kg
Shrunk weight of reference animal (SRW)	462 kg*
Breed modifier (BE)	1.00*
Gender Modifier (SEX)	1.00*
Adjustment for ionophores in diet (ADTV)	1.12*
Lactation modifier (L)	1.00*
Previous average monthly temperature (Tp)	20°C
Condition score (CS)	5

*Values from NRC (2000).

6.3 Weight Re-evaluation Test

The purpose of the weight re-evaluation test (WR) was to perform an additional evaluation of the weight-prediction component. This test was performed using feed intake and ration data supplied by the Department of Animal and Poultry Science for 130 cattle for the period of November 28, 2001 until January 16, 2002. The cattle were grouped into pens of 10 animals. These animals were from the same group of animals used in the EF test, however the

animals in each pen had been resorted and half of the animals were placed onto a limit-feeding program that was not compatible with the feed-prediction software developed for this project, so they were not used.

The feed intake and pen information were entered into a spreadsheet (Microsoft Excel, Microsoft Corporation, Redmond, WA). The equations used in the weight-prediction component (Section 5.4) were imported into the spreadsheet and used to predict the weight gain of the animals from their feed intake data.

The average starting body weights of the animals in each pen are shown in Table 6.6. The rations fed during this experiment are shown in Table 6.7. Table 6.8 lists the variables that were used in the weight prediction equation during this test.

Table 6.6: Average pen weights at the beginning of the weight re-evaluation test.

Pen	Average Starting Weight* (kg)	SD (kg)	Pen	Average Starting Weight* (kg)	SD (kg)
3	290.6	18.2	17	291.3	20.3
8	292.8	19.0	19	290.7	18.8
10	290.9	17.1	20	292.8	19.0
12	292.2	18.9	21	289.6	19.7
16	290.1	17.6	23	290.0	19.6

*Values are shrunk weights.

Table 6.7: Ration ingredients used in the weight re-evaluation test.

Date	Silage (%)*	Barley (%)*	Pellets JM2001 (%)*	Hay (%)*	Straw (%)*
11/28/01 to 12/5/01	40	27	8	25	0
12/6/01 to 12/19/01	45	27	8	20	0
12/20/01 to 1/4/02	45	27	8	15	15
1/5/02 to 1/16/02	45	20	8	12	15

*Percentages are on an as-fed basis.

Table 6.8: Weight prediction variables used in the weight re-evaluation test.

Variable	Value
Final shrunk body-weight (FSBW)	625 kg
Shrunk weight of reference animal (SRW)	462 kg*
Breed modifier (BE)	1.00*
Gender Modifier (SEX)	1.00*
Adjustment for ionophores in diet (ADTV)	1.12*
Lactation modifier (L)	1*

Previous average monthly temperature (Tp)	20°C
Condition score (CS)	5

*Values from NRC (2000).

6.4 Late Feeding Test

The LF test was conducted from April 11, 2002 until June 5, 2002. Ten pens of cattle, with 13 cattle per pen were used during this test. These animals were from the same group of cattle as from the WR test. The purpose of this test was to compare the feed-prediction capability of the software to that of the feedlot staff.

During this test, human experts made feed predictions and the cattle were fed according to these predictions. At the same time, the feed-prediction software was used to generate a separate set of feed predictions. The feed predictions generated by the software were based upon the feed predictions made by the human experts on the previous day. Thus, the two sets of data collected during this test were not independent.

The pens of animals were weighed at the beginning of the testing period to determine the mean body weight of the animals in each pen. Table 6.9 lists these weights. The animals were weighed every two weeks afterwards to determine the mean body weight of the animals in each pen. These measured weights were compared to the software-predicted weights at two-week intervals. Although the computer was predicting body weights, they were not used in the prediction of dry matter quantities because the cattle had been on feed for an amount of time greater than 35 days, as discussed in Section 3.1.2). Feed quantities were increased by 2.5% as discussed in Section 3.1.2. It was hypothesized that the computer-predicted body weights could be a useful management tool.

Table 6.9: Average animal body weight for each pen at the beginning of the late feeding test.

Pen	Average Starting Weight* (kg)	SD (kg)	Pen	Average Starting Weight* (kg)	SD (kg)
3	498.1	20.4	12	495.9	23.2
5	486.0	35.8	15	516.0	48.1
7	527.1	26.1	18	498.9	39.2
9	512.2	39.1	19	501.6	33.2
10	490.9	30.6	23	495.2	23.8

*Values are shrunk weights.

The feed-prediction software was set to increase feed quantities by 2.5%, every second day, when necessary. Table 6.10 lists the variables that were used by the weight-prediction component during this test.

Table 6.10: Weight prediction variables used in the late feeding test.

Variable	Value
Final shrunk body weight (FSBW)	625 kg
Shrunk weight of reference animal (SRW)	462 kg*
Breed modifier (BE)	1.00*
Modifier for bulls (SEX)	1.00*
Adjustment for ionophores in diet (ADTV)	1.12*
Lactation modifier (L)	1.00*
Previous average monthly temperature (Tp)	20°C
Condition score (CS)	5

*Values from NRC (2000).

The ration fed during this experiment consisted of 20% barley silage, 72% barley grain and 8% supplement pellets, on an as fed basis. Feeding occurred twice per day, with a load delivered to each pen in the morning and the remainder of the feed delivered in the afternoon.

The tractor computer and bunk reader computer were not used, in an effort to simplify the operation of the system. The mill software was modified so it could record the residuals and feed predictions made by the human experts. It was assumed that the human experts were accurate at mixing and delivering the correct rations to the pens in the correct quantity. Results from the EF test suggested that the staff were accurate at making correct feed deliveries, so this assumption was reasonable.

The bunk score setup was modified so that a desired range of residual was specified instead of the ten-point scoring system used previously. The desired level of residual was set between 4.5 kg and 10.1 kg per bunk on an as-fed basis. These values were suggested by the feedlot staff.

6.5 Final Testing

A final test was conducted at a commercial feedlot near Duck Lake, SK. The purpose of this test was to evaluate the feed-management software in a commercial feedlot setting.

During this test, a human expert made feed predictions and the cattle were fed according to these predictions. The feed-prediction software was used to generate a separate set of feed predictions and both sets of predictions were recorded so they could be compared at a later date.

Table 6.11 shows the variables that were used by the weight-prediction component during this test. Table 6.12 shows the number of cattle in each pen, and the average weight of the animals in each pen at the beginning of this test.

Table 6.13 lists the rations that were fed to the cattle during this test.

Table 6.11: Weight prediction variables used in the final feeding test.

Variable	Value
Final shrunk body weight (FSBW)	625 kg
Shrunk weight of reference animal (SRW)	462 kg*
Breed modifier (BE)	1.00*
Modifier for bulls (SEX)	1.00*
Adjustment for ionophores in diet (ADTV)	1.12*
Lactation modifier (L)	1.00*
Previous average monthly temperature (Tp)	20°C
Condition score (CS)	5

*Values from NRC (2000).

Table 6.12: Average animal weights at beginning of the final test.

Pen	Number of Head	Average Weight (kg)
5	134	541.3
6	158	544.3
7	138	547.2
8	61	546.2
9	89	548.1
10	141	546.8
C	19	542.3

Table 6.13: Rations fed during the final test.

Days	Barley Silage (% as fed)	Canola Silage (% as fed)	Barley Grain (% as fed)	Pellets (% as fed)
1-11	-	40.3	59.7	-
1214	-	35.02	62.9	2.08
15-24	33.23	-	62.84	3.93
25-29	31.57	-	62.59	5.84
30-35	31.1	-	60.68	8.22

The bunk score setup was modified so that the desired range of residual was specified as 3 to 5% of the previous day's feed, on an as fed basis. These values were suggested by the feedlot operator.

The DMI/BW parameters used during this experiment are listed in Table 6.14. These parameters are similar to the parameters used in the LF test. However, there were no rest days between consecutive feed increases.

Table 6.14: DMI/BW settings used in the final feeding test.

DMI/BW (%)	Increase* (%)	Rest Days**
0 to 1.5	10	0
1.5 to 2.0	10	0
2.0 to 2.25	5	0
>2.5	2.5	0

7. RESULTS AND DISCUSSION

7.1 Early Feeding Test

7.1.1 Animal Body-Weight Prediction Results

The results from the weight-prediction portion of this experiment are listed in Table 7.1. The difference between the means predicted weights and the means of the measured end of test weights were found to be different from zero, at a 5% significance level, using a t-test. This was likely due to the fact that the starting weights used in the experiment did not account for the five days of weight gain prior to the commencement of the test. It is possible that the results from the weight prediction portion of this experiment could have been more accurate if more accurate starting weights were used.

7.1.2 Feed-Prediction Results

Figures 7.1and 7.2 illustrate the feed prediction and feed intake graphs for pens 3 and 8. These graphs were noteworthy because there was too little residual feed from days 5 to 10. This suggested that the feed-prediction software was unable to increase the quantity of feed delivered to the cattle at a rate fast enough to match their appetites. In fact, on day 9, the computer-based feed predictions for pen 3 were overridden and a feed prediction made by the feedlot staff was used in its place.

The software was increasing the feed predictions at its maximum rate (10% per day) during this period. This suggested that the software should be modified so that it increases feed at a rate greater than 10%. However, it must be noted that this could increase the risk of the cattle experiencing acidosis. A second option is to leave the increase sizes at 10% and accept that there will be a certain frequency of empty bunks during feeding.

Table 7.1: Predicted and measured end of test animal weights from the early feeding test.

Pen	Predicted End of Test Weight* (kg)	Measured End of Test Weight* (kg)	SD (kg)
3	254.5	290.5	18.2
4	265.2	296.4	24.6
5	263.8	304.5	20.3
6	276.3	301.3	21.1
7	271.5	301.3	20.7
8	270.1	297.1	19.0
9	272.0	304.9	18.3
10	275.8	304.4	17.1
11	270.1	305.6	17.2
12	277.3	308.8	18.9

14	276.1	303.2	17.9
15	273.3	304.4	18.5
16	273.3	304.0	17.6
17	283.3	308.6	20.3
18	270.3	293.2	20.2
19	283.2	309.7	18.8
20	267.3	290.0	19.0
21	276.6	302.8	19.7
22	262.5	280.5	19.6
23	261.8	283.9	20.4
Mean	271.2**	299.8**	
SD	7.0	8.0	

*Values are shrunk weights.

**Values were significantly different at a 5% significance level.

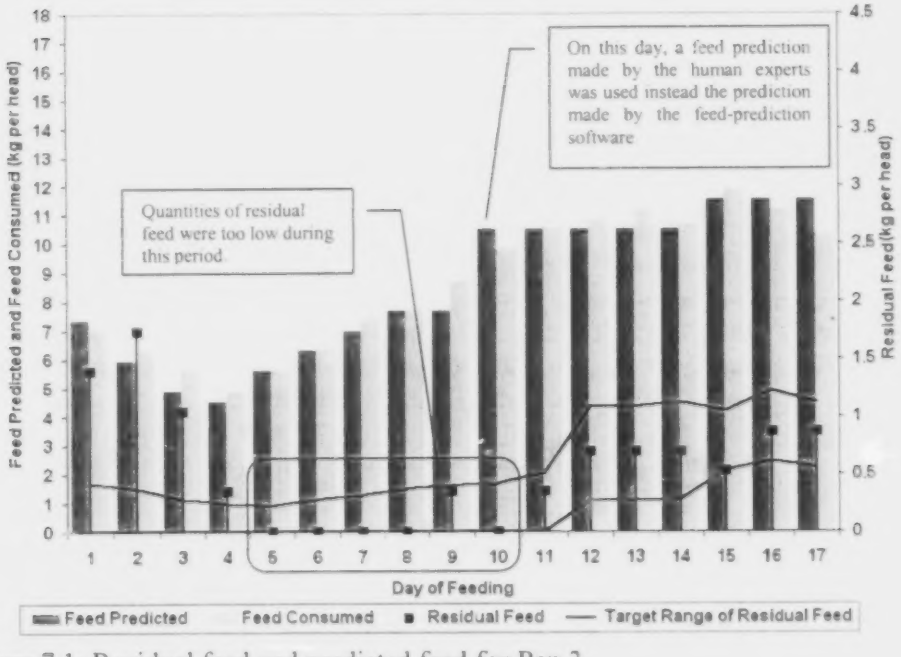

Feed Predicted and Feed Consumed (kg per head)
Residual Feed(kg per head)
Day of Feeding
On this day, a feed prediction made by the human experts was used instead the prediction made by the feed-prediction software
Quantities of residual feed were too low during this period
Feed Predicted
Feed Consumed
Residual Feed
Target Range of Residual Feed

Figure 7.1: Residual feed and predicted feed for Pen 3.

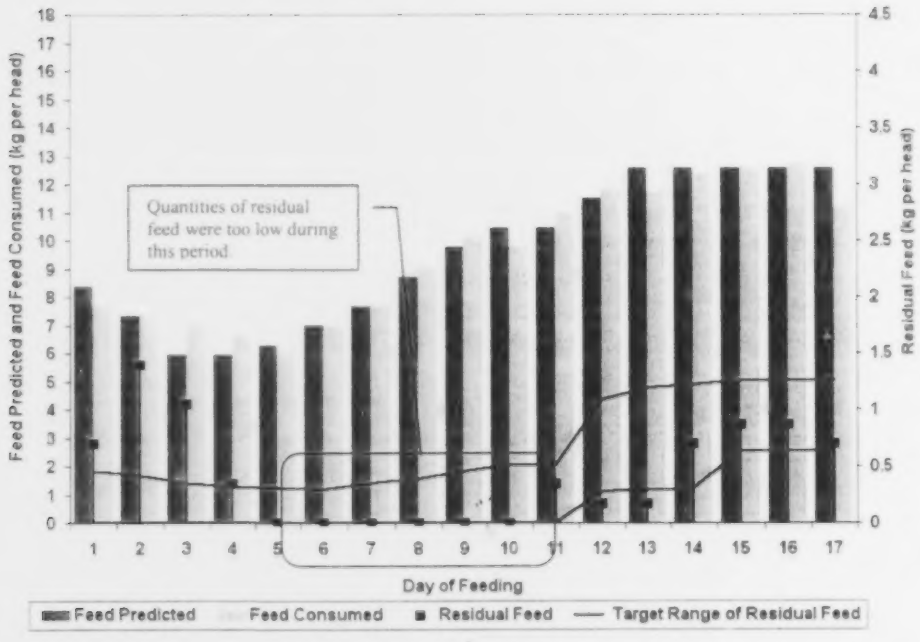

Quantities of residual feed were too low during this period
Feed Predicted and Feed Consumed (kg per head)
Residual Feed (kg per head)
Day of Feeding
Feed Predicted
Feed Consumed
Residual Feed
Target Range of Residual Feed

Figure 7.2: Residual feed and predicted feed for Pen 8.

Figures 7.3 and 7.4 illustrate the feed prediction and feed intake graphs for pens 18 and 22. These pens were noteworthy because they exhibited cyclical feed intake patterns. The first cycle of this pattern occurred because the feed-prediction software reduced the feed on several consecutive days (days 1 to 6). On day 7, the feedlot staff suggested that the feed had been reduced too greatly and their predictions were used in place of the software-based feed predictions. This is what caused the increase in predicted feed on day 7. The second cycle of this pattern occurred between days 7 and 11 when the feed-prediction software reduced the predicted feed quantities over several consecutive days. On day 12, the feedlot staff suggested that the feed had been reduced too greatly and their feed predictions were used in place of the software-based feed predictions. This is what caused the increase in predicted feed on day 12.

These cyclical intake patterns suggested that the feed-prediction software reduced feed quantities too rapidly when residual feed quantities were too large. This could be due to several reasons. First, reducing the feed levels by an amount equal to 133% of the residual might be too much. Secondly, allowing feed quantities to be decreased on consecutive days might cause feed levels to decrease too rapidly. Thirdly, defining the levels of acceptable residual as percentages of the previous day's feed delivery may have contributed to the problem. When feed quantities were reduced, so too did the level of acceptable residual. When the upper limit of the acceptable residual was decreased, the feed-prediction software became more sensitive to residual quantities. In other words, quantities of residual feed that would have caused the feed-prediction software to maintain feed quantities (or even increase them) caused it to decrease them instead.

It was hypothesized preventing the feed-prediction software from reducing feed quantities on consecutive days could prevent the software from decreasing feed quantities too rapidly. This change was implemented in the version of the software used in the EF test, as discussed in Section 5.3.2. Further, it was also hypothesized that defining the limits of acceptable residual as fixed quantities (instead of percentages) could prevent the software from being too sensitive to residual quantities when feed were decreased, as discussed in section 5.3.2.

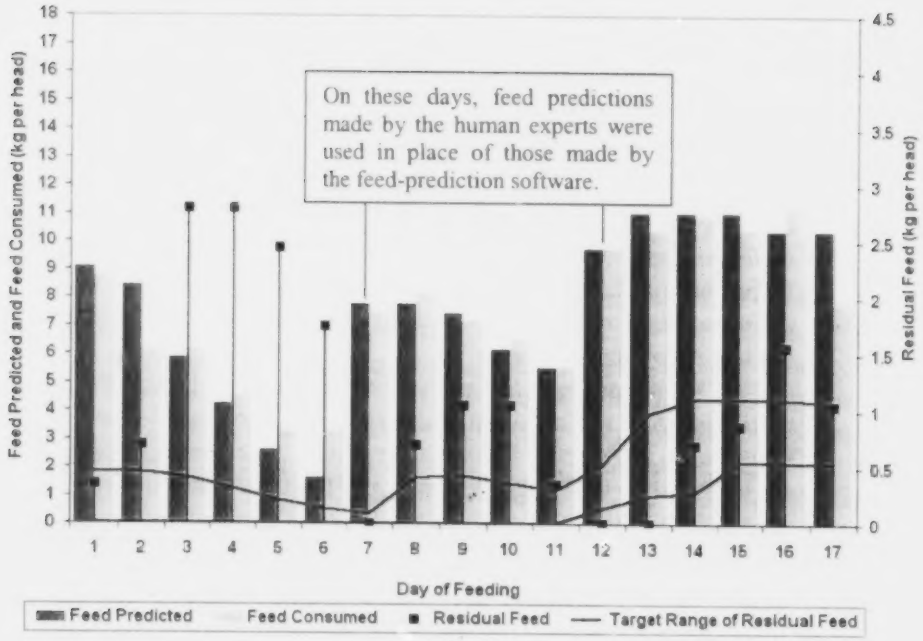

On these days, feed predictions made by the human experts were used in place of those made by the feed-prediction software.
Feed Predicted and Feed Consumed (kg per head)
Residual Feed (kg per head)
Day of Feeding
Feed Predicted
Feed Consumed
Residual Feed
Target Range of Residual Feed

Figure 7.3: Residual feed and predicted feed for pen 18.

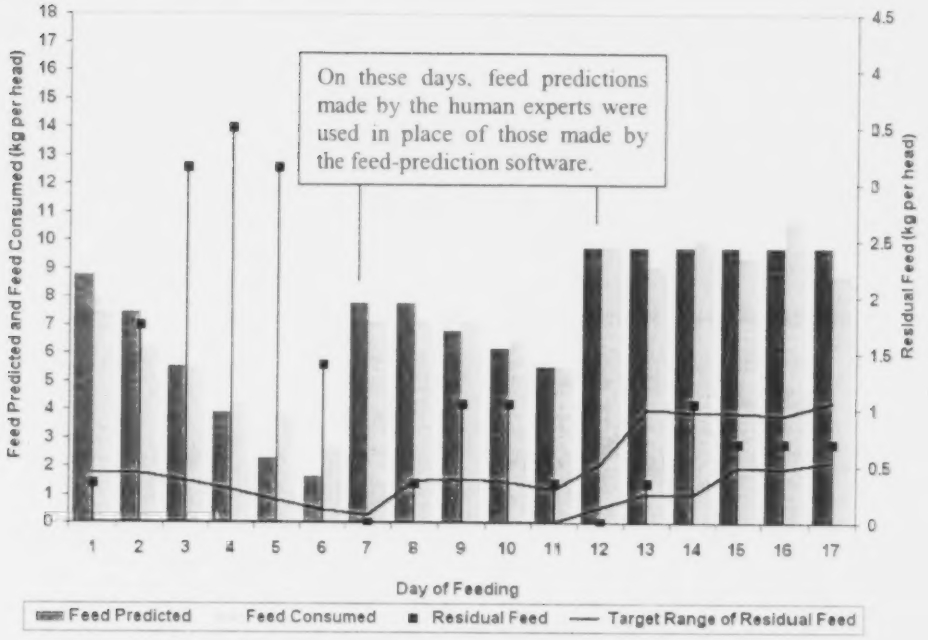

On these days, feed predictions made by the human experts were used in place of those made by the feed-prediction software.
Feed Predicted and Feed Consumed (kg per head)
Residual Feed (kg per head)
Day of Feeding
Feed Predicted
Feed Consumed
Residual Feed
Target Range of Residual Feed

Figure 7.4: Residual feed and predicted feed for pen 22.

7.1.3 Feed-Delivery Accuracy

It was important to assess the ability of the operators to deliver the correct quantity of feed to the pens. The effectiveness of the feed-prediction software could be compromised if the quantity of feed delivered to the pens varied greatly from the predicted values. An analysis was performed that compared the difference between the total quantity of feed predicted and the total quantity of feed delivered to each pen.

The quantities of computer-predicted feed and the quantities of feed delivered to the pens were summed for the entire 21-day feeding period. The percentage difference between the two was determined. These results are summarized in Table 7.2. The mean of the total quantities of feed delivered to the pens differed from the mean of total predicted quantities by 2.0 kg (0.1%), with a standard deviation of 33.8 kg (1.3%). The mean of the total quantity of feed predicted did not differ from the mean of the total quantity of feed delivered at a 5% significance level, using a t-test to determine if the differences between the means differed significantly from zero.

Table 7.2: Comparison between total feed predicted and total feed delivered for the 21-day duration of the early feeding test.

Pen	Total Feed Predicted* (kg)	Total Feed Delivered* (kg)	Difference (kg)	Percent Difference
3	2340.1	2390.0	49.9	2.1
4	2693.9	2716.6	22.7	0.8
5	3097.5	3056.7	-40.8	-1.3
6	3052.2	3024.9	-27.2	-0.9
7	2444.4	2476.2	31.7	1.3
8	2725.6	2739.2	13.6	0.5
9	2757.4	2689.3	-68.0	-2.5
10	2730.2	2757.4	27.2	1.0
11	2716.6	2761.9	45.4	1.7
12	3247.2	3215.4	-31.7	-1.0
14	2984.1	2970.5	-13.6	-0.5
15	2793.7	2798.2	4.5	0.2
16	2644.0	2707.5	63.5	2.4
17	3052.2	3034.0	-18.1	-0.6
18	2290.2	2276.6	-13.6	-0.6
19	3142.9	3133.8	-9.1	-0.3
20	2512.5	2498.9	-13.6	-0.5
21	2943.3	2966.0	22.7	0.8

22	2213.2	2235.8	22.7	1.0
23	2462.6	2435.4	-27.2	-1.1
Mean	2742.2**	2744.2**	2.0	0.1
SD	300.4	287.7	33.8	1.3

*Values are on an as-fed basis.

**Values were not significantly different at a 5% significance level.

7.1.4 Hardware Evaluation

The range of the wireless Ethernet connection was limited because there were a large number of metal objects that interfered with the radio signals transmitted between the mill computer and the tractor computer. These objects included the metal roof and walls of the feed-mill, the feed-handling and feed-processing equipment present at the mill site and the tractor cab. When the tractor computer needed to transfer information to the mill computer, it was parked approximately 5 m from the feed-mill office. This ensured uninterrupted communication with the feed-mill computer. This location was convenient because it was located near the bins that dispensed the feed pellets used in the feed loads. It is likely that the range of the wireless Ethernet connection could be improved by adding external antennae to the WAP connected to the mill computer.

Several limitations were encountered with the tractor computer. First, when operating in bright sunlight, the operators found that it was difficult to see the screen. The second problem was that the area available for using the mouse on the tractor computer was limited, which made it difficult to enter information into the mobile-unit software. The tractor cab was a dusty environment, so the mouse had to be cleaned daily. Otherwise it would not work properly. It should be noted that the tractor computer was still functional at the end of this test despite being exposed to these dusty conditions.

7. 2 Weight Re-evaluation Test

The results from the WR test are shown in Table 7.3. The results showed that the mean of the predicted end of test pen weights differed significantly from the mean of the measured end of test pen weights, at a 5% significance level, using a t-test.

Table 7.3: Weight prediction results from the weight re-evaluation test.

Pen	Predicted Weight* (kg)	Measured Weight* (kg)	SD (kg)
3	332.5	358.2	20.6
8	341.4	351.3	24.4
10	337.8	350.0	19.3
12	349.5	354.1	18.5
16	342.0	358.3	20.2
17	339.4	352.7	19.7
19	346.4	353.8	24.4

20	339.1	356.3	23.4
21	339.3	351.9	27
23	333.4	344.9	21.8
Mean	340.1**	353.2**	
SD	5.2	4.0	

*Values are shrunk weights.

**Values were significantly different at a 5% significance level.

7.3 Late Feeding Test

7.3.1 Animal Body-Weight Prediction Results

The differences between the predicted animal body weights and the measured animal body weights for the LF test are shown in Tables 7.4, 7.5, 7.6 and 7.7. It should be noted that between weeks 6 and 8, animals that had reached the desired level of finishing were removed from the pens.

The computer-predicted weights were compared to the measured weights for each week of the experiment. The means of the computer predicted weights were compared to the means of the measured weights and a t-test was used to determine if the difference between the means differed significantly from zero. The weight-prediction software was only able to accurately predict the average body weights of the animals in the pens on one of the four weeks, thus it was concluded that it did not predict animal body weights accurately.

This inability to predict the average body weights of the animals in the pens did not affect the operation of the feed-prediction software. The feed-prediction software did not require predicted weights to determine feed quantities because the cattle had been on feed for a time greater than the previously discussed time limits, which were 20 days for yearlings and 35 days for calves.

The analysis of these weight predictions were included because it was hypothesized, by the authors, that knowledge of animal body weights during the feeding period could be a useful to the feedlot operators.

Table 7.4: Weight prediction results from the late feeding test (Week 2).

Pen	Predicted Weight* (kg)	Measured Weight* (kg)	SD (kg)
3	521.16	538.73	19.4
5	508.48	533.31	39.2
7	530.15	534.36	27.9
9	536.09	543.70	38.7
10	517.87	536.50	28.1
12	522.21	529.88	26.5
15	537.75	542.06	49.5
18	523.50	539.46	40.2
19	524.62	526.33	33.5
23	518.26	527.50	23.6
Mean	524.01**	535.18**	

SD	8.79	5.98

*Values are shrunk weights.

**Values were significantly different at a 5% significance level.

Table 7.5: Weight prediction results from the late feeding test (Week 4).

Pen	Predicted Weight* (kg)	Measured Weight* (kg)	SD (kg)
3	546.6	542.20	22.1
5	534.0	544.90	36.5
7	550.5	552.10	31.3
9	558.7	557.80	39.3
10	546.0	538.20	35.2
12	550.6	546.90	25.7
15	560.4	562.90	53.5
18	549.6	542.80	39.0
19	548.7	549.50	31.0
23	548.8	536.60	23.2
Mean	549.4**	547.4**	
SD	7.2	8.4	

*Values are shrunk weights.

**Values were not significantly different at a 5% significance level.

Table 7.6: Weight prediction results from the late feeding test (Week 6).

Pen	Predicted Weight* (kg)	Measured Weight* (kg)	SD (kg)
3	574.36	606.42	24.8
5	559.45	598.62	35.0
7	570.67	597.92	35.4
9	582.21	606.02	40.2
10	570.17	596.36	39.0
12	577.71	592.15	29.6
15	581.93	590.43	40.4
18	575.17	582.12	38.3
19	570.50	586.77	27.6
23	572.29	589.04	24.3
Mean	573.4**	594.6**	
SD	6.6	8.0	

*Values are shrunk weights.

**Values were significantly different at a 5% significance level.

Table 7.7: Weight prediction results from the late feeding test (Week 8).

Pen	Predicted Weight* (kg)	Measured Weight* (kg)	SD (kg)
3	597.94	586.50	19.9
5	582.53	572.60	27.3
7	589.35	569.60	42.3
9	605.06	585.80	17.4
10	593.50	576.10	29.9
12	602.48	592.80	10.9
15	600.32	590.70	22.6
18	599.39	586.40	34.9
19	592.51	585.50	22.8
23	584.10	595.40	23.0
Mean	594.7**	584.1**	
SD	7.7	8.6	

*Values are shrunk weights.

**Values were significantly different at a 5% significance level.

7.3.2 Feed-Prediction Results

During the LF test, the human experts assigned an average of 10.85 kgDM head^{-1} of feed the pens while the feed-prediction software assigned an average of 10.80 kgDM head^{-1} to the pens. It should be noted that these means were nearly identical because the feed-prediction software made its feed predictions based upon the feed quantities previously assigned by the human experts.

The feed-prediction software increased feed quantities 99 times, with a mean increase of 2.5% relative to the quantity of feed predicted for the previous day. The human experts increased feed quantities 154 times, with a mean increase of 4.8%, relative to the quantity of feed predicted for the previous day. The magnitudes of the feed increases made by the feed-prediction software were limited to 2.5% because the cattle had been on feed for an amount of time greater than 35 days. These results are included in Table 7.8.

The feed-prediction software made fewer increases to feed quantities because of the rest days setting that prevented it from increasing feed quantities on consecutive days. The human experts made a larger number of increases to feed quantities because they routinely increased feed quantities on consecutive days, hence the disparity. These results are summarized in Table 7.8.

The feed-prediction software and the human experts made approximately the same number of decreases to feed quantities (136 versus 140). However, the magnitude of the decreases made by the feed prediction software were larger than those made by the human experts (6.7 versus 5.2%).

Table 7.8: Number of adjustments made to feed quantities by the feed-prediction software and the human experts during the LF Test.

	Increases			Decreases		
	Number	Magnitude (%)*	SD	Number	Magnitude (%)**	SD
Human Experts	154	4.8	3.8	140	5.2	3.1
Computer	99	2.5	0.6	136	6.7	5.4

*Size of feed increases, as a percentage of the previous day's feed delivered.
**Size of feed decreases, as a percentage of the previous day's feed delivered.

7.4 Results from Final Testing

A total of 35 feed predictions were made for each of the seven pens. The feed-prediction software increased feed amounts 92 times with an average increase of 7.2%, relative to the amount of feed delivered on the previous day. The human experts increased feed amounts 72 times with an average increase of 8.5%, relative to the quantity of feed delivered on the previous day. The feed prediction software decreased feed 52 times, with an average decrease of 8.9%, relative to the amount of feed delivered on the previous day. The human expert decreased feed 40 times, with an average decrease of 7.6%, relative to the amount of feed delivered on the previous day. These results are summarized in Table 7.9.

Table 7.9: Number of adjustments made to feed quantities by the feed-prediction software and the human experts during the final test.

	Increases			Decreases		
	Number	Magnitude (%)*	SD	Number	Magnitude (%)**	SD
Human Experts	72	8.5	17.1	40	5.2	31.4
Computer	92	7.2	8.9	52	6.7	14.3

*Size of feed increases, as a percentage of the previous day's feed delivered.
**Size of feed decreases, as a percentage of the previous day's feed delivered.

A regression analysis was performed to determine the correlation between the computer-based feed predictions and the feed predictions made by the human experts for the LF test and final testing. Results indicated that the correlation was greater for the LF test. These results are presented in table 7.10.

Table 7.10: Correlation between computer-based feed predictions and predictions made by feedlot experts.

	r^2
Late Feeding Test	0.52
Final Testing	0.15

The lesser degree of correlation in the final testing was likely due to the fact that the feed-prediction software and the feedlot experts responded differently to the residual quantities. For example, the feedlot experts had a tendency to leave feed quantities unchanged when the residual feed quantities were less than 3%, whereas the feed-prediction software increased feed quantities. Further, when the residual feed quantity was greater than 5%, the feedlot experts would often leave feed quantities unchanged, whereas the feed prediction software reduced feed quantities.

During the final test, several limitations were observed with the weight-prediction software. The first limitation occurred because animals were often moved in and out of pens. Animals introduced into pens were often of different weights than the animals already in the pen. Subsequent weight predictions would not be accurate because the average weight of the animals in the pen had changed.The second limitation arose from the fact that animals of different breeds were contained in the pens. This would affect the accuracy of the weight-prediction software, given that the animal breed is considered in the weight-prediction equations.

8. CONCLUSIONS

8.1 Feed Prediction

During the EF test, the feed-prediction software reduced feed quantities too rapidly when residual feed quantities were too large. The feed-prediction software was improved by modifying it so that decreases in feed quantities could not occur on consecutive days. This improved version of the software was used in the LF test.

During the EF test, the target level of residual (bunk score 1) was defined as a percentage of the previous day's feed delivery. This meant that when feed quantities were reduced, so too were the limits of acceptable residual. Consequently, when residuals were too large, the feed-prediction software was more likely to reduce feed quantities instead of maintaining or increasing them. It was hypothesized that defining the limits of acceptable residual as fixed quantities, rather than percentages, could alleviate this problem. This change was incorporated into the software used in the LF test.

During the EF test, the software was unable to increase feed quantities at a rate fast enough to match the appetites of the cattle. This indicates that the magnitudes of feed increases should be increased, or a certain frequency of empty bunks should be accepted as a normal part of the feeding process.

During the LF test the feed-prediction software made 99 increases to feed delivery quantities while the human experts made 154. The software made fewer increases to feed quantities because of the rest days parameter, which prevented it from making feed increases on consecutive days. The feedlot experts routinely made increases to feed deliveries on consecutive days, hence the disparity.

The mean size of the increases made by the feed-prediction software was 2.5%, while the mean size of the increases made by the human experts was 4.8%. This indicated that the feed-prediction software increased feed quantities at a slower rate than the human experts. This could result in more frequent empty bunks.

During the LF test, the feed-prediction software and the human experts made approximately the same number of decreases to feed delivery quantities (136 versus 140). However, the mean size of the decreases made by the feed-prediction software was 6.7% versus 5.2% for the human experts. This indicated that the feed-prediction software reduced feed quantities more aggressively than the human experts when residuals were too large. This could result in more frequent empty bunks.

8.2 Operator Accuracy

During the EF test, the ability of the operators to deliver the correct quantity of feed to the pens was measured. It was important that the correct quantity of feed was delivered because deviations in feed deliveries, especially accidental over feedings, could cause acidosis. On average, the total quantities of feed delivered to the pens differed from the predicted quantities by an average of 2.0 kg (0.1%) with a standard deviation of 33.8 kg (1.3%). This result was

encouraging because it meant that the pens received the correct quantity of feed, on average.

8.3 Body-Weight Prediction

Results from the EF test suggested that the weight-prediction component did not accurately predict the body weights of the cattle. However, it should be noted that there were 5 days of body weight gain that were not included in the weight prediction. With those days included, it is possible that the weight prediction would have been more accurate.

Results from the WR test indicated that the means of the predicted animal body weights not accurately predicted, as well.

Results from the LF test indicated that the accuracy of the weight predictions varied over time. The animal body weights were accurately predicted only in the second week of the trial. There was not sufficient data available to determine what caused these variations. It should be noted that the feed-prediction component did not use the DMI/BW management parameter during the EF test because the cattle were fed a finishing ration. Thus, the accuracy of the weight predictions did not affect the feed prediction accuracy of the software. It was hypothesized that the computer-predicted weights could be a useful management tool that would help to determine when the cattle were ready for market. However, given the inconsistencies in the weight prediction accuracy, this would not be useful in practice.

8.4 Hardware

The hardware proved to be adequate for this project. It is recommended that the wireless access point connected to the mill computer be outfitted with external antennae to extend the coverage of the wireless network, for the sake of convenience.

The bunk reader computer was too bulky to be carried during the bunk reading process. Replacing it with a smaller handheld unit is recommended.

8.5 Conclusions from Final Testing

In general, the experts at the commercial feedlot had a greater tolerance for sub-optimal delivery quantities. The allowable residual levels should be reviewed and confirmed prior to further development or revisions to the software.

The inclusion of the weight-prediction software has a number of limitations, and these were highlighted in the final test. It may be advantageous to explore alternate methods to estimate the amount of consumption, relative to animal size.

8.6 Future Work

The equations used for predicting average weights of the animals in each pen did not produce accurate results. This could be due to the fact that the equations used for estimating the amount of energy in the diet available for maintenance and gain (Equations 5.17 and 5.18) were developed under different conditions than what were present in this experiment. These equations were

developed in the United States, where environmental conditions and feeding systems are different from those in Canada. Further research needs to be undertaken to evaluate these relationships for cattle in western Canada.

An opportunity still exists to test the feed-prediction software in an independent trial, where the feed prediction ability of the software would be compared to that of the feedlot staff. The performance of the two systems could be compared based on parameters that include rate of weight gain, quantity of feed used for weight gain and animal health.

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APPENDIX A: NETWORK HARDWARE SETUP

A.1 Mill Computer Network Hardware Setup

Connect the Wireless Access Point (WAP11) to the USB port of the mill computer using the USB cable. Connect the Ethernet card to the Ethernet hub using 10base-t Ethernet cable. It does not matter what port the connection is made to. Also, connect the wireless access point to the same Ethernet hub using CAT-5 Ethernet cable. Once again, it does not matter which port the connection is made to. There is no software to install or settings to enter for the WAP11, only the aforementioned connections. Figure A1 illustrates these hardware connections.

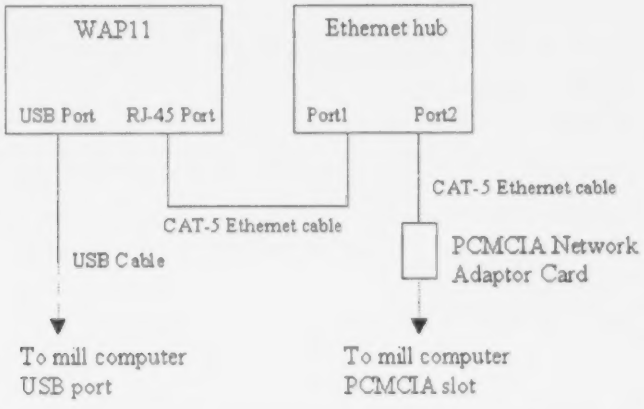

Figure A1: Network hardware connections to the mill computer.

A.2 Network TCP/IP Settings

Table A2 lists the TCP/IP settings for all the devices connected to the wireless network.

Table A2: TCP/IP settings for wireless network.

Item	IP Address	Workgroup	Computer Name
Tractor Computer	1.1.1.1	Feedlot	Tractor
Bunk Reader Computer	1.1.1.2	Feedlot	Bunk Reader
Mill Computer	1.1.1.3	Feedlot	Mill
WAP11	1.1.1.4	n/a	n/a

A.3 Mill Computer ODBC Setup

Mill Database

Data source Name: MILL_DB
Database: C:\Program Files\Project1\mill.mdb.

Predictive Database

Data source Name: PREDICTIVE_DB, and
Database selection: C:\Program Files\Project1\predictive.mdb.

A.4 Tractor Computer ODBC Setup

Truck Database

Data source Name: TRUCK_DB, and
Database selection: C:\Program Files\TRUCK\truck.mdb

Predictive Database

Data source Name: PREDICTIVE_DB, and
Database selection: \\MILL\Program Files\Project1\predictive.mdb

Mill Database

Data source Name: MILL_DB, and
Database selection: \\MILL\Program Files\Project1\mill.mdb

A.5 Bunk Reader Computer ODBC Setup

Truck Database

Data source Name: TRUCK_DB, and
Database selection: C:\Program Files\TRUCK\truck.mdb

Predictive Database

Data source Name: PREDICTIVE_DB, and
Database selection: \\MILL\Program Files\Project1\predictive.mdb

Mill Database

Data source Name: MILL_DB
Database selection: \\MILL\Program Files\Project1\mill.mdb.

APPENDIX B: SERIAL INTERFACE

The following table lists the pin connections for connecting the EZ150 scale indicator to the tractor computer.

Table A.1: Pin connections for tractor computer and EZ150.

Tractor Computer (COM1)		EZ150 (J904)
Pin 2	→	Pin2
Pin3	→	Pin3
Pin5	→	Pin5

The serial communication interface operates at 1200 baud with 1 start bit, 7 data bits, 1 even parity bit and 1 stop bit.

APPENDIX C: MILL COMPUTER SOFTWARE INSTALLATION

Install the mill software onto the mill computer using the LV Control CD-ROM and running setup.exe in the \Mill_application\package directory. Install the mill software to the default directory, which is \Program Files\Project1.

Install LVLink on the mill computer with the LV Control CD-ROM by running setup.exe in the \LVLink directory. Install LVLink to the default directory, which is \Program Files\LVServer.

When LVLink has been run for the first time it will display the configuration screen. Enter the following information:
Server computer name: MILL,
Server IP address: 1.1.1.3,
LV server socket: 998,
Truck1 IP address: 1.1.1.1 and
Truck2 IP address: 1.1.1.2.

Leave the fields for Truck2 and Truck3 IP addresses empty because they are not present in the system. This screen can be accessed at a later time by pressing the "SETUP" button. The password is "setup".

APPENDIX D: MOBILE UNIT SOFTWARE INSTALLATION

D.1 Bunk Reader Computer

Install the truck software on the bunk reader computer by running setup.exe located in the \Truck_app directory of the LV Controls CD-ROM. Install the truck software to the default directory, which is \Program Files\TRUCK.

To access the configuration screen for the truck computer press "s" while on the main screen. The password is "support". Enter the following information:
Setup Password: support,
Mill ODBC: MILL_DB,
Mill IP address: 1.1.1.3,
Mill Port: 998,
Truck IP address: 1.1.1.2,
Truck ID: 2,
Driver ID: 1 and
Trk Database path: C:\Program Files\TRUCK\truck.mdb.

Note that the setup password can be left blank so that there is no password to needed for accessing this screen.

D.2 Tractor Computer

Install the truck software on the tractor computer by running setup.exe located in the \Truck_app directory of the LV Controls CD-ROM. Install the truck software to the default directory, which is \Program Files\TRUCK.

To access the configuration screen for the truck computer press "s" while on the main screen. The password is "support". Enter the following information:
Setup Password: support,
Mill ODBC: MILL_DB,
Mill IP address: 1.1.1.3,
Mill Port: 998,
Truck IP address: 1.1.1.1,
Truck ID: 1,
Driver ID: 1 and
Trk Database path: C:\Program Files\TRUCK\truck.mdb.

Note that the setup password can be left blank so that there is no password to needed for accessing this screen.

APPENDIX E: MOBILE-UNIT SOFTWARE OPERATION

The main screen of the mobile-unit software is shown in Figure E.1.

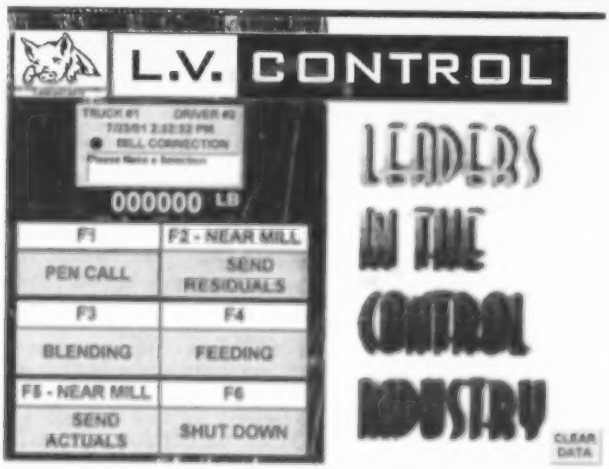

Figure E1: Mobile-unit software main screen.

E.1 Bunk Reading

The PEN CALL function is used to record the residuals present in each bunk prior to feeding. When it is activated the screen shown of Figure E2 is displayed. The pen call screen contains a listing of the pens that need their residual feed recorded (a), and an array of numbers used to enter the size of the residual in pounds (b). The aggression section (c) and the bunk cleanup section (d), were not used in this study.

The operator will visit all the pens and enter their residuals. After the residuals from all of the pens have been recorded, the operator will exit this screen and return to the main screen.

The information gathered by this part of the truck software consists of the pen number and the residual for each pen number. The operator will then use the SEND RESIDUALS function to send this information to the mill database on the mill computer when all of the bunks have been read.

APPENDIX E: MOBILE-UNIT SOFTWARE OPERATION

The main screen of the mobile-unit software is shown in Figure E.1.

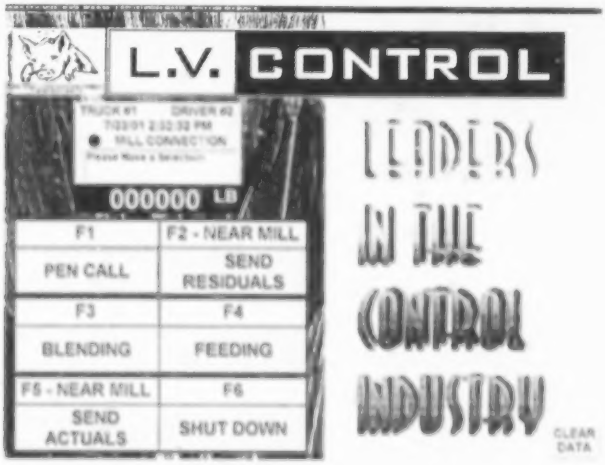

Figure E1: Mobile-unit software main screen.

E.1 Bunk Reading

The PEN CALL function is used to record the residuals present in each bunk prior to feeding. When it is activated the screen shown of Figure E2 is displayed. The pen call screen contains a listing of the pens that need their residual feed recorded (a), and an array of numbers used to enter the size of the residual in pounds (b). The aggression section (c) and the bunk cleanup section (d), were not used in this study.

The operator will visit all the pens and enter their residuals. After the residuals from all of the pens have been recorded, the operator will exit this screen and return to the main screen.

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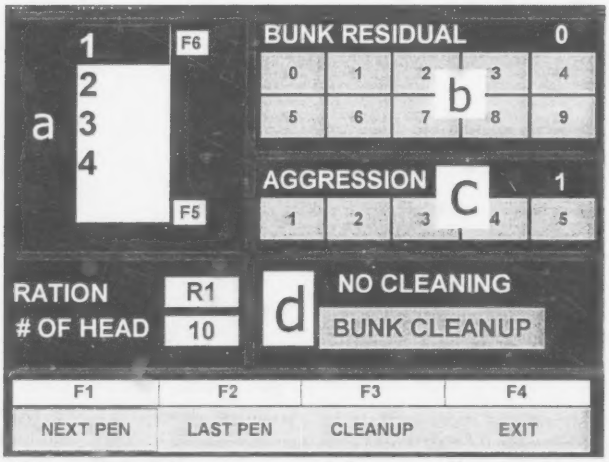

Figure E2: The screen used for recording bunk residuals.

E.2 Blending Feed

The BLENDING function displays a listing of loads of feed that need to be mixed. An example of this is shown in Figure E3. In this example, the operator selects the load displayed on the screen.

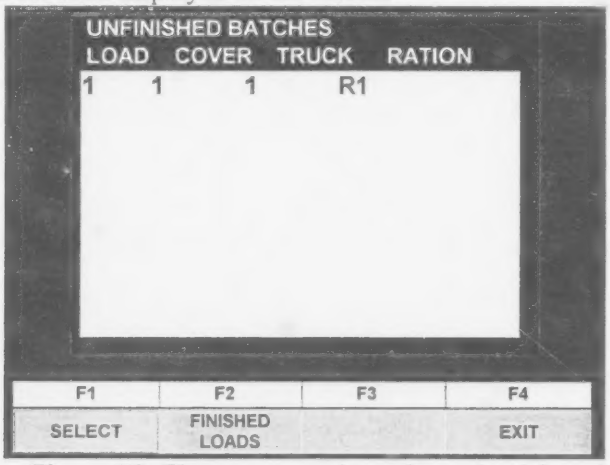

Figure E3: The screen used to select a load for mixing.

The load selected requires 450 pounds of barley and 680 pounds of barley silage. The software displays the screen shown in Figure E4. This screen displays the total weight of the load that is being mixed (a), which is 1130 pounds (450 pounds + 680 pounds). The software automatically selects the first ingredient from the list of feed commodities in the load, which is barley grain (b). The software displays a listing of how much of that ingredient needs to be loaded (c). The gross weight of the scale indicator is shown (d), which is zero because no feed commodities have been loaded into the mixer wagon. The operator will proceed to load 450 pounds of barley grain into the mixer wagon, at which point the quantity to be loaded (c) will be 0 pounds and the gross weight (d) will be 450 pounds. The operator will select the COMPLETE button, which will record the quantity of barley grain that was loaded into the mixer wagon.

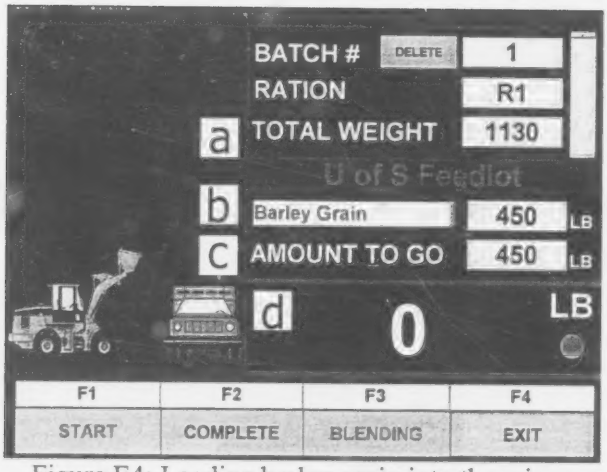

Figure E4: Loading barley grain into the mixer wagon.

Next, the operator selects the next ingredient from the list, which is barley silage. This is shown in Figure E5. The selected commodity is now barley silage (b), the quantity that needs to be loaded (c), is 680 pounds. The gross weight (d), is 450 pounds, which is the quantity of barley grain loaded previously. The operator will then proceed to load 680 pounds of barley silage, at which point the quantity that needs to be loaded (c) and the gross weight (d) will be 0 pounds and 1130 pounds, respectively. When there are no more feed commodities to load the operator exits this screen and returns back to the main screen and proceeds to access the FEEDING function.

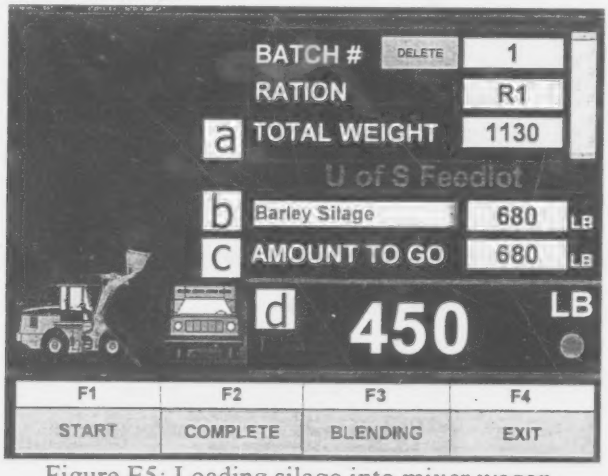

Figure E5: Loading silage into mixer wagon.

The information gathered from this part of the software consists of a unique identifier that identifies the current load and the mass of each ingredient that was used for the load. This information is recorded within a database on the truck computer.

E.3 Feeding

The FEEDING function will display the screen shown in Figure E6. This screen shows the gross weight displayed by the scale indicator (a) and a listing of the bunks that need to be fed from the current load (b). A progress bar that

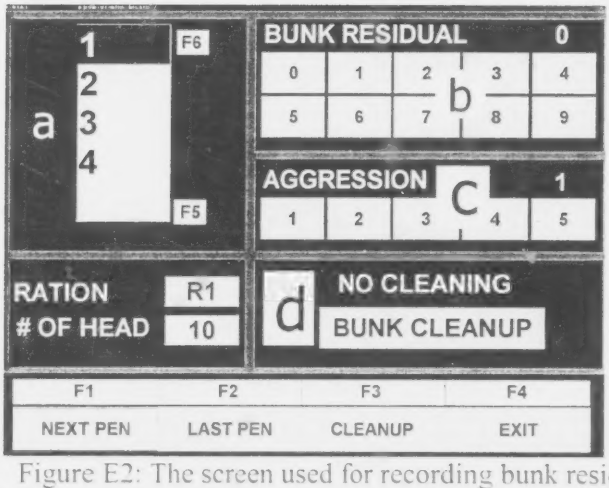

Figure E2: The screen used for recording bunk residuals.

E.2 Blending Feed

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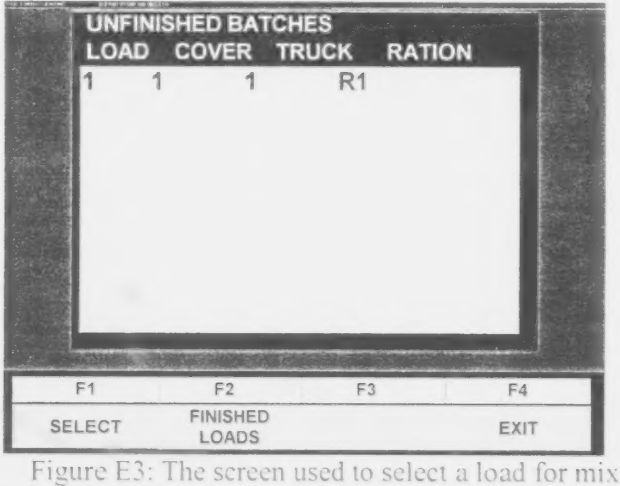

Figure E3: The screen used to select a load for mixing.

The load selected requires 450 pounds of barley and 680 pounds of barley silage. The software displays the screen shown in Figure E4. This screen displays the total weight of the load that is being mixed (a), which is 1130 pounds (450 pounds + 680 pounds). The software automatically selects the first ingredient from the list of feed commodities in the load, which is barley grain (b). The software displays a listing of how much of that ingredient needs to be loaded (c). The gross weight of the scale indicator is shown (d), which is zero because no feed commodities have been loaded into the mixer wagon. The operator will proceed to load 450 pounds of barley grain into the mixer wagon, at which point the quantity to be loaded (c) will be 0 pounds and the gross weight (d) will be 450 pounds. The operator will select the COMPLETE button, which will record the quantity of barley grain that was loaded into the mixer wagon.

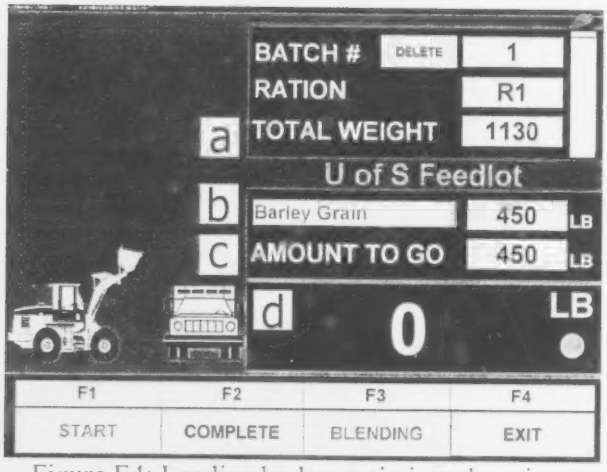

Figure E4: Loading barley grain into the mixer wagon.

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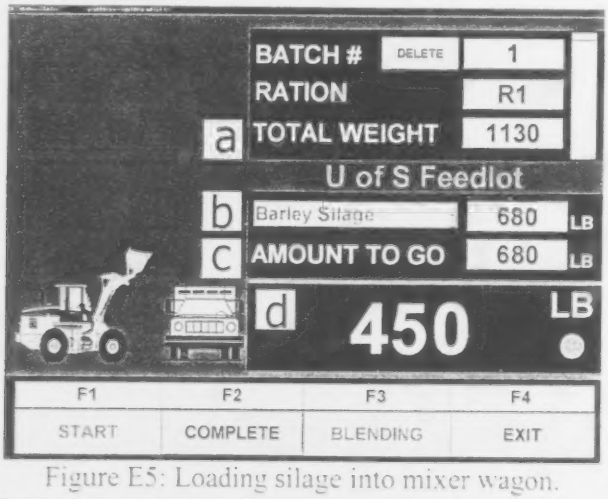


Figure E5: Loading silage into mixer wagon.

The information gathered from this part of the software consists of a unique identifier that identifies the current load and the mass of each ingredient that was used for the load. This information is recorded within a database on the truck computer.

E.3 Feeding

The FEEDING function will display the screen shown in Figure E6. This screen shows the gross weight displayed by the scale indicator (a) and a listing of the bunks that need to be fed from the current load (b). A progress bar that

illustrates the progress of the feed delivery (c) is also shown. Also shown are the quantities of feed that needs to be unloaded into this pen (d) and the quantity that has been unloaded into this bunk (e). In this example, the operator moves to pen 1, selects pen 1 from the pen list, presses the START PEN button, and begins to unload the feed into the bunk. The gross weight (a) is 1130 pounds because no pens have been fed from the feed commodities that were loaded previously. The quantity that has been unloaded (e), is 0 because the operator has just begun feeding. The operator begins to unload the 220 pounds of feed that are indicated by the TARGET number (d).

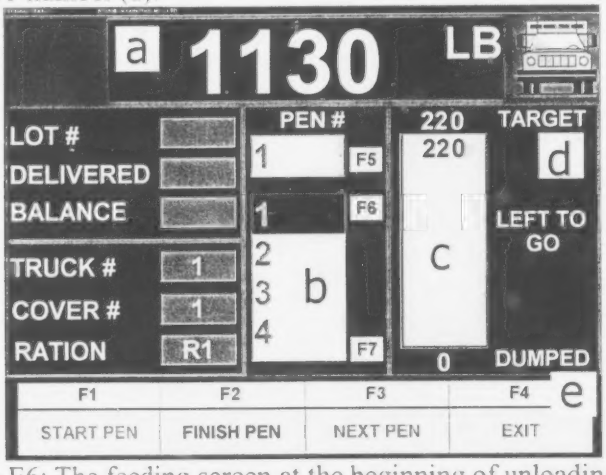
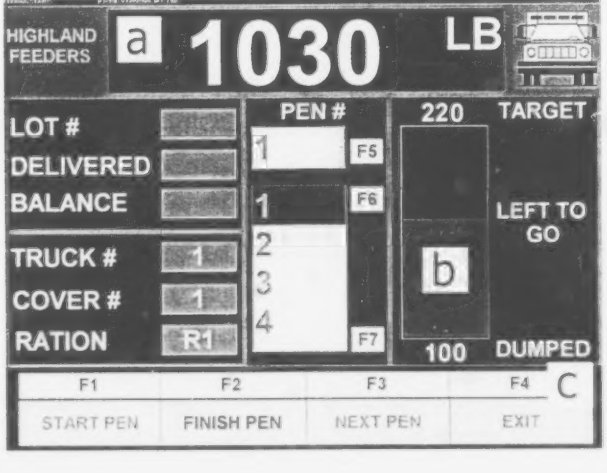


Figure E6: The feeding screen at the beginning of unloading feed.

Figure E7 shows the screen of Figure 4.10 after 100 pounds of feed have been unloaded, indicated by the DUMPED quantity (c). The gross weight (a) is now 1030 pounds because 100 pounds of feed have been unloaded from the mixer wagon into the bunk. The progress bar (b) has been updated and it indicates that there are 120 pounds of feed remaining to be unloaded into this bunk. The operator will proceed until the progress bar (b) indicates that there are 0 pounds of feed remaining. When the feed has been unloaded the operator will press the FINISH PEN button. The operator will select the next pen from the pen list or press the NEXT PEN button to proceed onto the next pen.



illustrates the progress of the feed delivery (c) is also shown. Also shown are the quantities of feed that needs to be unloaded into this pen (d) and the quantity that has been unloaded into this bunk (e). In this example, the operator moves to pen 1, selects pen 1 from the pen list, presses the START PEN button, and begins to unload the feed into the bunk. The gross weight (a) is 1130 pounds because no pens have been fed from the feed commodities that were loaded previously. The quantity that has been unloaded (e), is 0 because the operator has just begun feeding. The operator begins to unload the 220 pounds of feed that are indicated by the TARGET number (d).

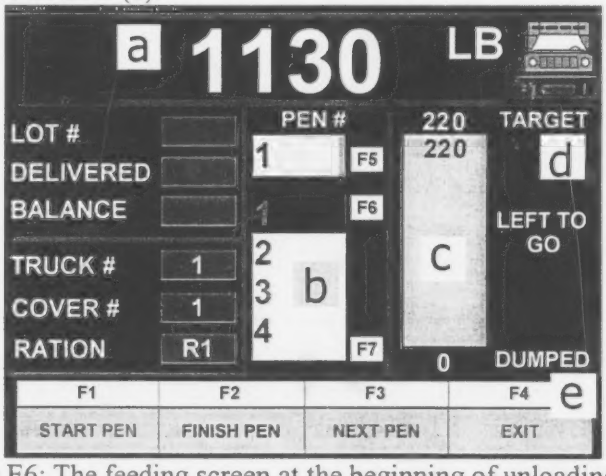


Figure E6: The feeding screen at the beginning of unloading feed.

Figure E7 shows the screen of Figure 4.10 after 100 pounds of feed have been unloaded, indicated by the DUMPED quantity (c). The gross weight (a) is now 1030 pounds because 100 pounds of feed have been unloaded from the mixer wagon into the bunk. The progress bar (b) has been updated and it indicates that there are 120 pounds of feed remaining to be unloaded into this bunk. The operator will proceed until the progress bar (b) indicates that there are 0 pounds of feed remaining. When the feed has been unloaded the operator will press the FINISH PEN button. The operator will select the next pen from the pen list or press the NEXT PEN button to proceed onto the next pen.

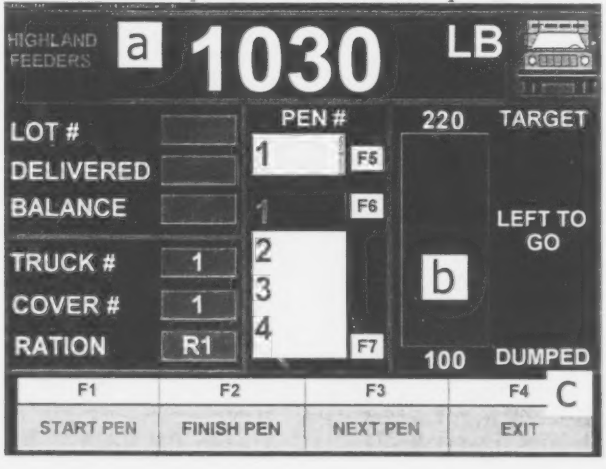


Figure E7: Feeding screen after unloading 100 lbs of feed.

The data collected at this point consisted of the pen number, the mass of feed delivered to each pen from the current load, and the load identifier. This information is stored in a database on the truck computer. When the current load of feed has been delivered (i.e. the mixer wagon is empty) the operator will use the SEND ACTUALS function to send the gathered data to the mill computer.

APPENDIX F: MILL SOFTWARE CONFIGURATION

F.1 Entering Commodities

To enter commodities into the commodity inventory select Edit→Rations from the main screen of the mill software and select the Edit Commodities tab which displays the screen shown in Figure F1. To enter a commodity, type its description (e.g. barley silage) into the COMMODITY DESCRIPTION box. Enter the commodity's ME (Mcal kg^{-1} (dry matter basis) and DM (as a percent) into the appropriate boxes. Press the ADD NEW commodity to save the commodity. Repeat this process for all commodities required.

To edit a commodities description, ME, or DM, select the commodity from the listing at the top of the screen and re-enter the data in the appropriate column. To delete a commodity select the commodity from the commodity list on the top of the screen and press the DELETE SELECTED COMMODITY button.

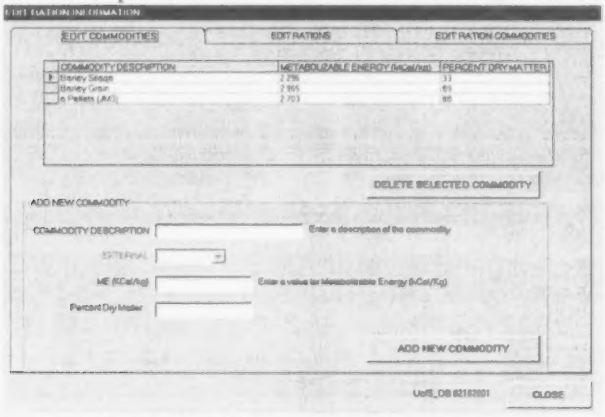


Figure F1: Edit commodities screen.

F.2 Creating Rations

To create a ration, select Edit→Rations from the main screen of the mill software and select the Edit Rations tab. This will bring up the screen shown in Figure F2. The ration name defines the name of the ration (e.g Starter Ration). The ration short name is an abbreviated version of the ration name that is displayed within the mobile unit software (e.g SR). The ration order defines the order in the ration sequence that the ration is fed. The days on ration determines the number of days the ration should be fed to the cattle..

Press the ADD NEW RATION button to save the newly entered ration. Repeat this process for each ration that needs to be created.

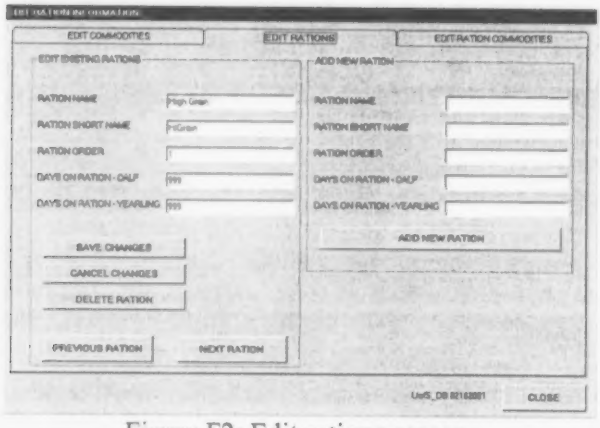


Figure F2: Edit rations screen.

F.3 Editing and Deleting Rations

To edit a ration, select Edit→Rations from the main screen of the mill software and select the Edit Rations tab. This will bring up the screen shown in Figure F2. The information contained in the boxes shown on the left side of Figure F2 can be changed. Pressing the SAVE CHANGES button will save the changes that were made.

To delete and existing ration, use NEXT RATION or PREVIOUS RATION buttons to select the desired ration. Then press the DELETE RATION button to delete the ration.

F.4 Adding Commodities to a Ration

To create a ration, select Edit→Rations from the main screen of the mill software and select the Edit Rations Commodities tab This will bring up the screen shown in Figure F3. Use the PREVIOUS RATION or NEXT RATION buttons to cycle through the rations until the desired ration is displayed. To add a commodity to the ration select a commodity from the Commodity drop down box. Next, enter the as-fed percentage of this commodity in the ration into the As Fed Percentage Box. Repeat this process for all commodities that are in the ration. Note that the as-fed percentages for the commodities within a ration must add to 100 percent.

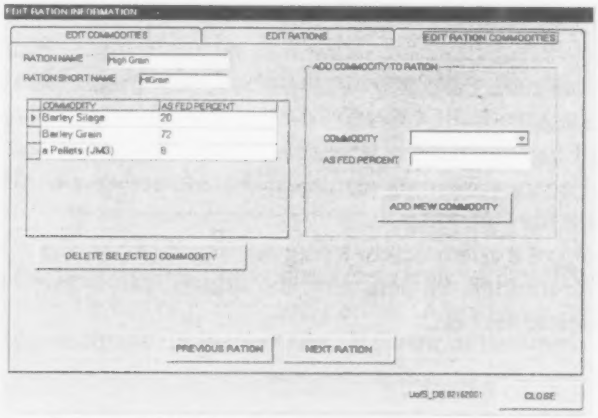


Figure F3: Edit ration commodities screen.

F.5 Editing and Deleting Ration Commodities

APPENDIX F: MILL SOFTWARE CONFIGURATION

F.1 Entering Commodities

To enter commodities into the commodity inventory select Edit→Rations from the main screen of the mill software and select the Edit Commodities tab which displays the screen shown in Figure F1. To enter a commodity, type its description (e.g. barley silage) into the COMMODITY DESCRIPTION box. Enter the commodity's ME (Mcal kg^{-1} (dry matter basis) and DM (as a percent) into the appropriate boxes. Press the ADD NEW commodity to save the commodity. Repeat this process for all commodities required.

To edit a commodities description, ME, or DM, select the commodity from the listing at the top of the screen and re-enter the data in the appropriate column. To delete a commodity select the commodity from the commodity list on the top of the screen and press the DELETE SELECTED COMMODITY button.

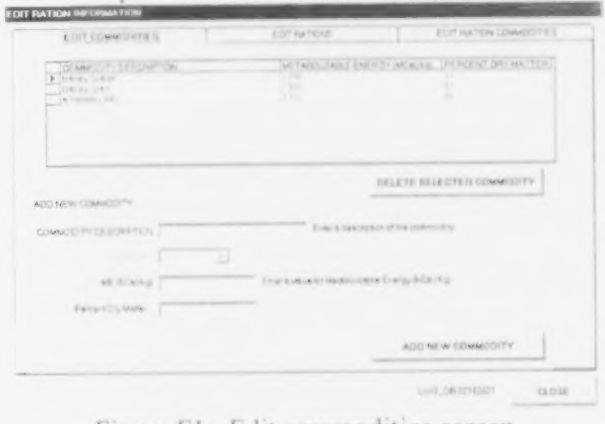


Figure F1: Edit commodities screen.

F.2 Creating Rations

To create a ration, select Edit→Rations from the main screen of the mill software and select the Edit Rations tab. This will bring up the screen shown in Figure F2. The ration name defines the name of the ration (e.g Starter Ration). The ration short name is an abbreviated version of the ration name that is displayed within the mobile unit software (e.g SR). The ration order defines the order in the ration sequence that the ration is fed. The days on ration determines the number of days the ration should be fed to the cattle..

Press the ADD NEW RATION button to save the newly entered ration. Repeat this process for each ration that needs to be created.

Figure F2: Edit rations screen.

F.3 Editing and Deleting Rations

To edit a ration, select Edit→Rations from the main screen of the mill software and select the Edit Rations tab. This will bring up the screen shown in Figure F2. The information contained in the boxes shown on the left side of Figure F2 can be changed. Pressing the SAVE CHANGES button will save the changes that were made.

To delete and existing ration, use NEXT RATION or PREVIOUS RATION buttons to select the desired ration. Then press the DELETE RATION button to delete the ration.

F.4 Adding Commodities to a Ration

To create a ration, select Edit→Rations from the main screen of the mill software and select the Edit Rations Commodities tab. This will bring up the screen shown in Figure F3. Use the PREVIOUS RATION or NEXT RATION buttons to cycle through the rations until the desired ration is displayed. To add a commodity to the ration select a commodity from the Commodity drop down box. Next, enter the as-fed percentage of this commodity in the ration into the As Fed Percentage Box. Repeat this process for all commodities that are in the ration. Note that the as-fed percentages for the commodities within a ration must add to 100 percent.

Figure F3: Edit ration commodities screen.

F.5 Editing and Deleting Ration Commodities

Select Edit→Rations from the main screen of the mill software and select the Edit Rations tab. This will bring up the screen shown in Figure 3. Use the PREVIOUS RATION or NEXT RATION buttons to cycle through the rations until the desired ration is displayed. When a ration is selected its commodities are shown on the left side of the screen shown in Figure F3. The as fed percentage of each commodity, shown on the left, can be changed by clicking on the commodity and re-entering the as fed percent data.
To delete a commodity, select it from the list and press the DELETE SELECTED COMMODITY button.2.1 Adding Ration Commodities

F.6 Adding Pens

To add a pen, select Edit→Pens from the main menu of the mill software and select the Add Pens tab. This will display the screen shown in Figure F4. The pen number is the number that uniquely identifies the pen. The number of head is the number of animals in the pen. The start weight is the average start weight (lbs) of the animals in the pen at the time of their first feeding. The finish weight is the average expected weight (lbs) of the animals when they are finished. The marbling setting is used by the weight-prediction software. The calf or yearling indicates whether the pen has calves or yearlings in it.

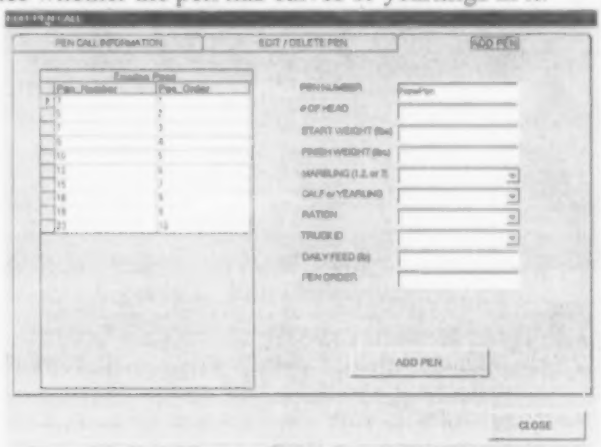


Figure F4: Add pens screen.

F.7 Editing Pens

To edit a pen, select Edit→Pens from the main menu of the mill software and select the Edit Pens tab, which will display the screen shown in Figure F5. Use the PREVIOUS PEN or the NEXT PEN buttons to cycle through the pens until the desired one is selected. Entering new values into the appropriate boxes will change the data displayed by this screen. Changes are saved automatically when they are entered.

To add a delete a pen, use the PREVIOUS PEN or NEXT PEN buttons to cycle through the pens until the desired pen is selected. Press the DELETE PEN to delete the pen.

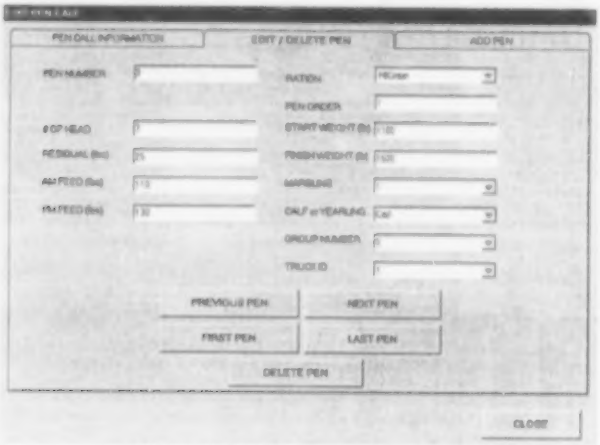


Figure F5: Edit pens screen.

F.8 Cover and Truck Settings

To change these settings, select Settings→Cover and Truck Settings from the main screen of the mill software which brings up the screen shown in Figure F6. The number of trucks defines the number of feed delivery vehicles. The number of covers defines the number of times per day the pens are fed. The max truck weight defines the maximum quantity of feed the truck can hold in units of pounds.

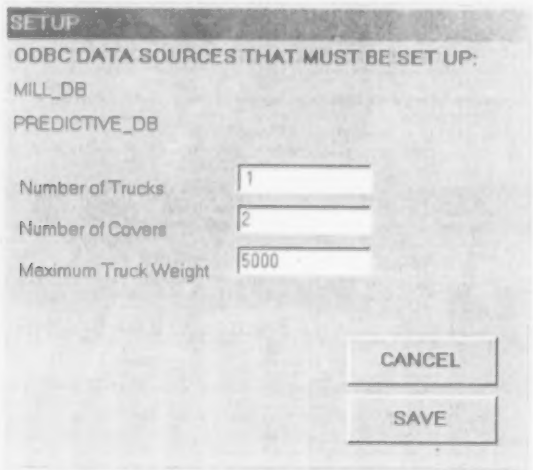


Figure F6: Cover and truck settings screen.

F.9 Calf and Yearling DMI/BW Settings

To change these settings, select Settings → DMI/BW Settings from the main screen of the mill software. The screen for entering DMI/BW settings is shown in Figure F7. Each pair of boxes denotes a range of DMI/BW. Enter the DMI/BW values into the boxes in increasing order. Also, enter the number of rest days and percentage increase (in percent) for each pair of settings.

Select Edit→Rations from the main screen of the mill software and select the Edit Rations tab. This will bring up the screen shown in Figure 3. Use the PREVIOUS RATION or NEXT RATION buttons to cycle through the rations until the desired ration is displayed. When a ration is selected its commodities are shown on the left side of the screen shown in Figure F3. The as fed percentage of each commodity, shown on the left, can be changed by clicking on the commodity and re-entering the as fed percent data.
To delete a commodity, select it from the list and press the DELETE SELECTED COMMODITY button.2.1 Adding Ration Commodities

F.6 Adding Pens

To add a pen, select Edit→Pens from the main menu of the mill software and select the Add Pens tab. This will display the screen shown in Figure F4. The pen number is the number that uniquely identifies the pen. The number of head is the number of animals in the pen. The start weight is the average start weight (lbs) of the animals in the pen at the time of their first feeding. The finish weight is the average expected weight (lbs) of the animals when they are finished. The marbling setting is used by the weight-prediction software. The calf or yearling indicates whether the pen has calves or yearlings in it.

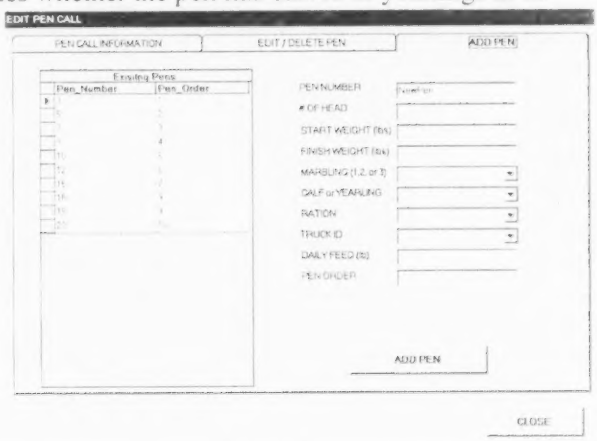


Figure F4: Add pens screen.

F.7 Editing Pens

To edit a pen, select Edit→Pens from the main menu of the mill software and select the Edit Pens tab, which will display the screen shown in Figure F5. Use the PREVIOUS PEN or the NEXT PEN buttons to cycle through the pens until the desired one is selected. Entering new values into the appropriate boxes will change the data displayed by this screen. Changes are saved automatically when they are entered.

To add a delete a pen, use the PREVIOUS PEN or NEXT PEN buttons to cycle through the pens until the desired pen is selected. Press the DELETE PEN to delete the pen.

Figure F5: Edit pens screen.

F.8 Cover and Truck Settings

To change these settings, select Settings→Cover and Truck Settings from the main screen of the mill software which brings up the screen shown in Figure F6. The number of trucks defines the number of feed delivery vehicles. The number of covers defines the number of times per day the pens are fed. The max truck weight defines the maximum quantity of feed the truck can hold in units of pounds.

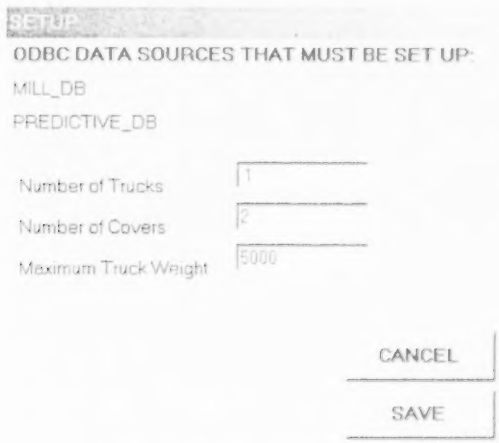


Figure F6: Cover and truck settings screen.

F.9 Calf and Yearling DMI/BW Settings

To change these settings, select Settings → DMI/BW Settings from the main screen of the mill software. The screen for entering DMI/BW settings is shown in Figure F7. Each pair of boxes denotes a range of DMI/BW. Enter the DMI/BW values into the boxes in increasing order. Also, enter the number of rest days and percentage increase (in percent) for each pair of settings.

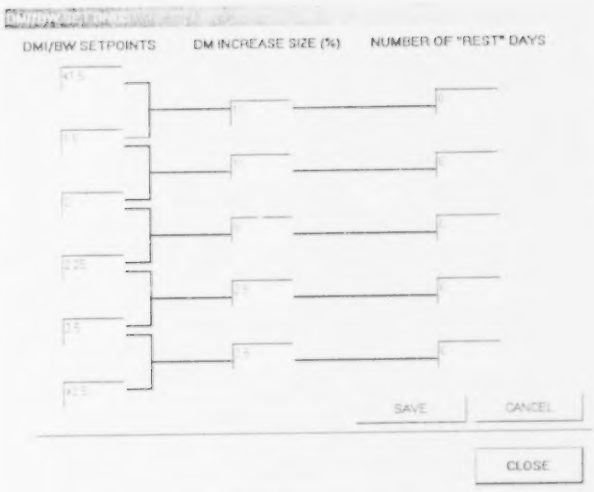


Figure F7: DMI/BW settings screen.

F.10 Residual Setting

To change these settings, select Settings→Residual from the main screen of the mill software. The screen shown in Figure F8 is displayed. The minimum residual is the minimum desired residual that should be present in the bunk and maximum residual is the maximum desired residual that should be present in the bunk. Enter these values in units of pounds.

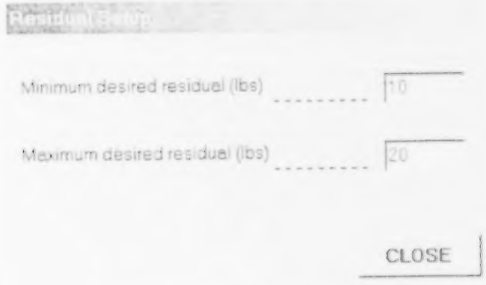


Figure F8: Residual settings.

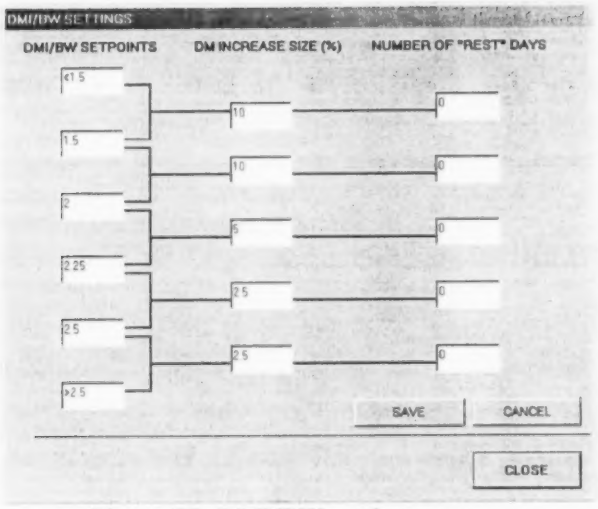


Figure F7: DMI/BW settings screen.

F.10 Residual Setting

To change these settings, select Settings→Residual from the main screen of the mill software. The screen shown in Figure F8 is displayed. The minimum residual is the minimum desired residual that should be present in the bunk and maximum residual is the maximum desired residual that should be present in the bunk. Enter these values in units of pounds.

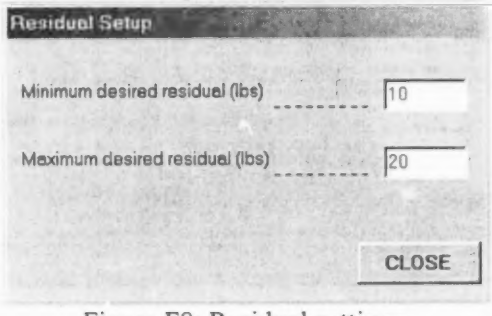


Figure F8: Residual settings.

APPENDIX G: GRAPHS FROM EARLY FEEDING TEST

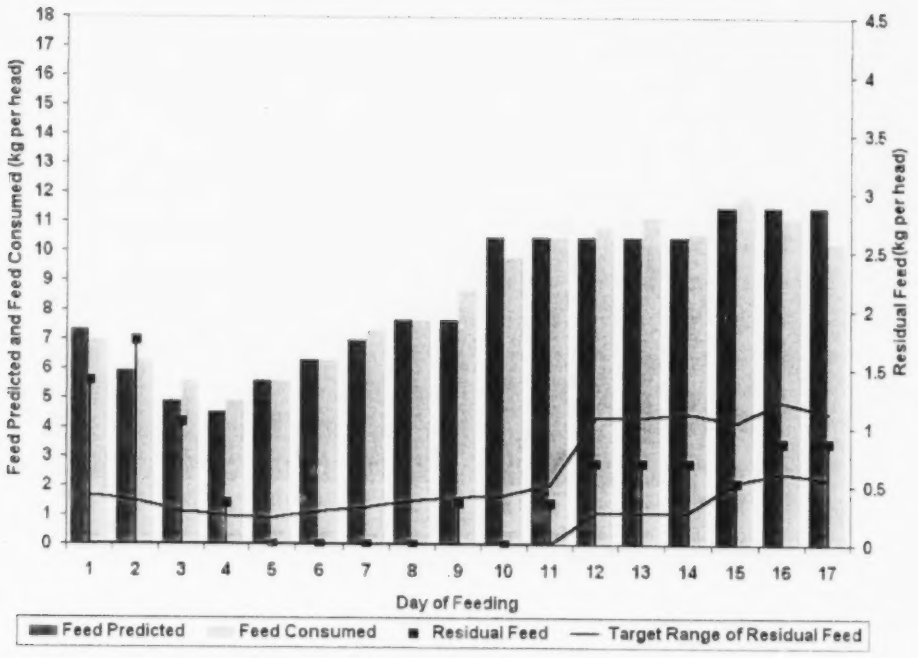


Figure G1: Predicted feed, feed consumed and residual feed (as-fed basis) per head for Pen 3.

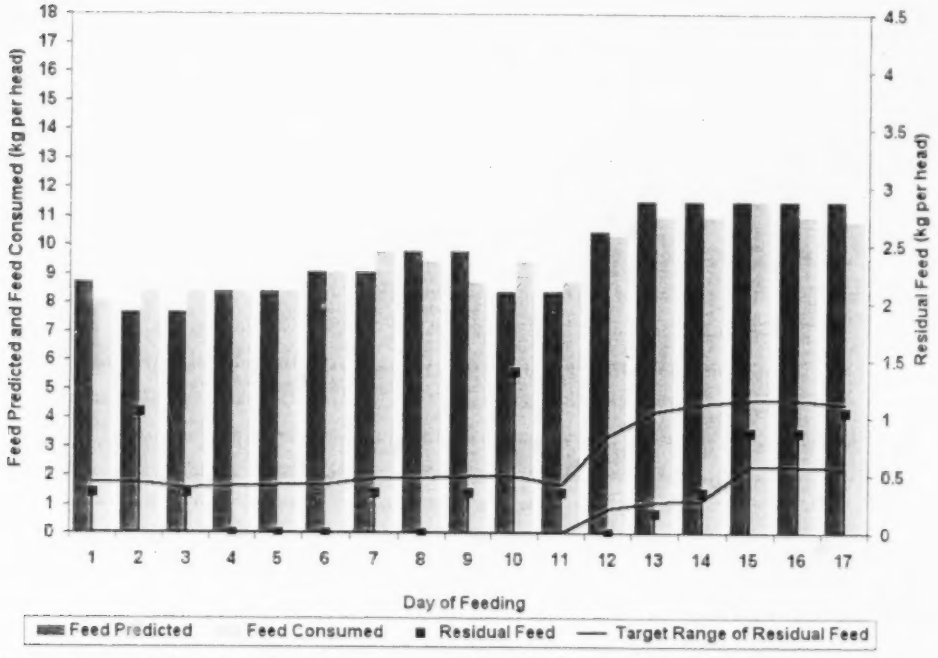


Figure G2: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 4.

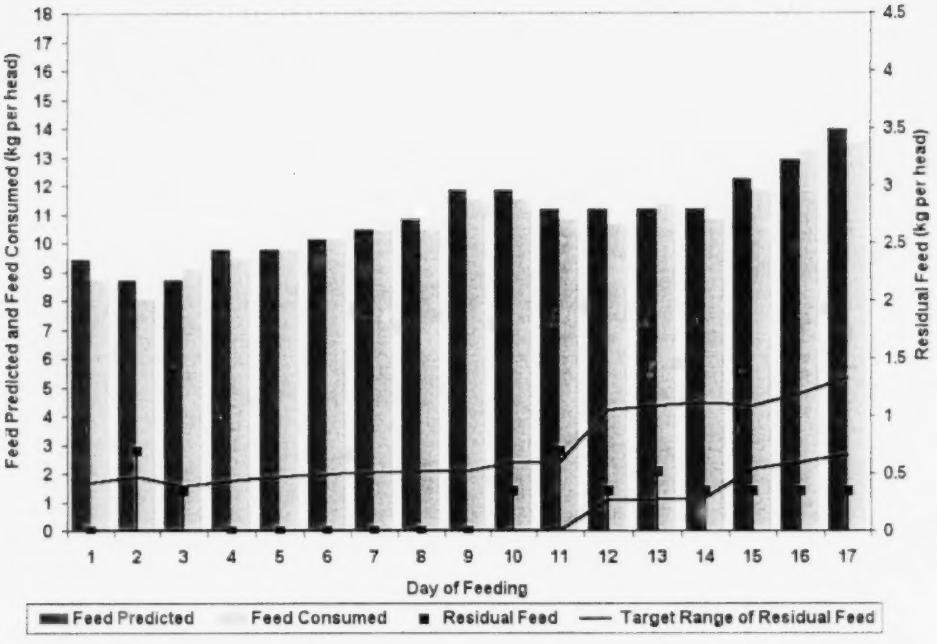


Figure G3: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 5.

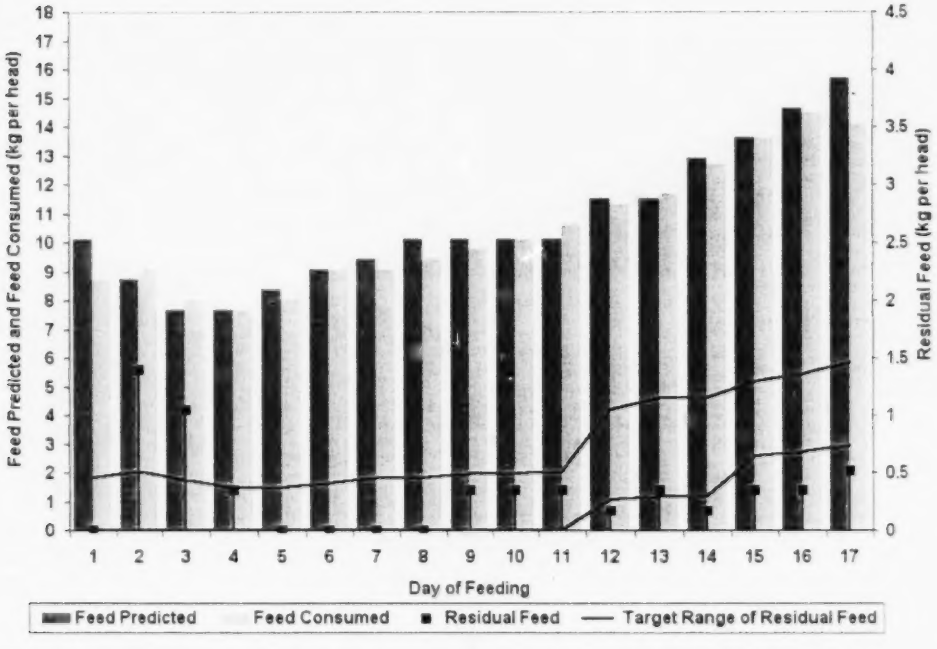


Figure G4: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 6.

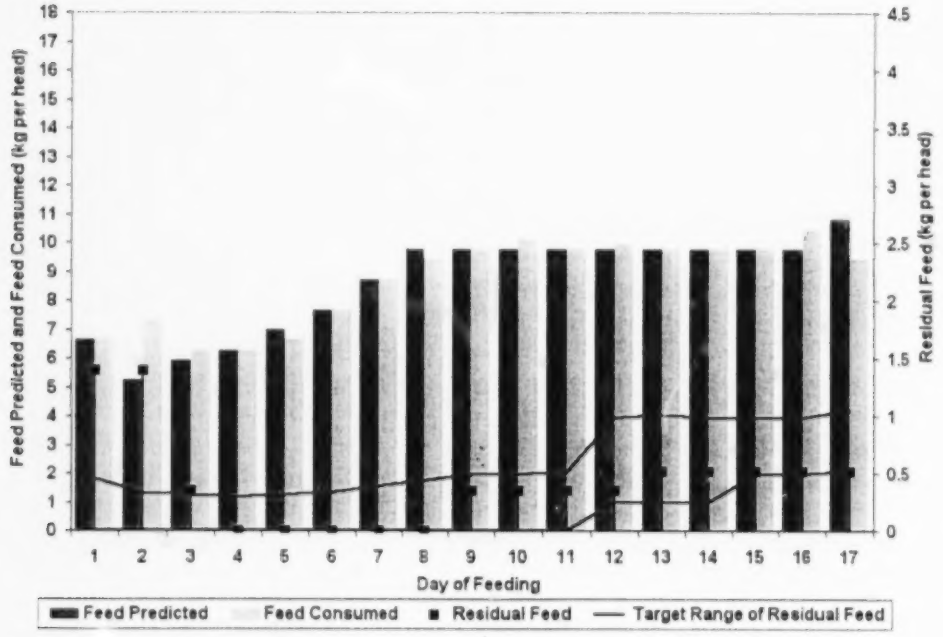


Figure G5: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 7.

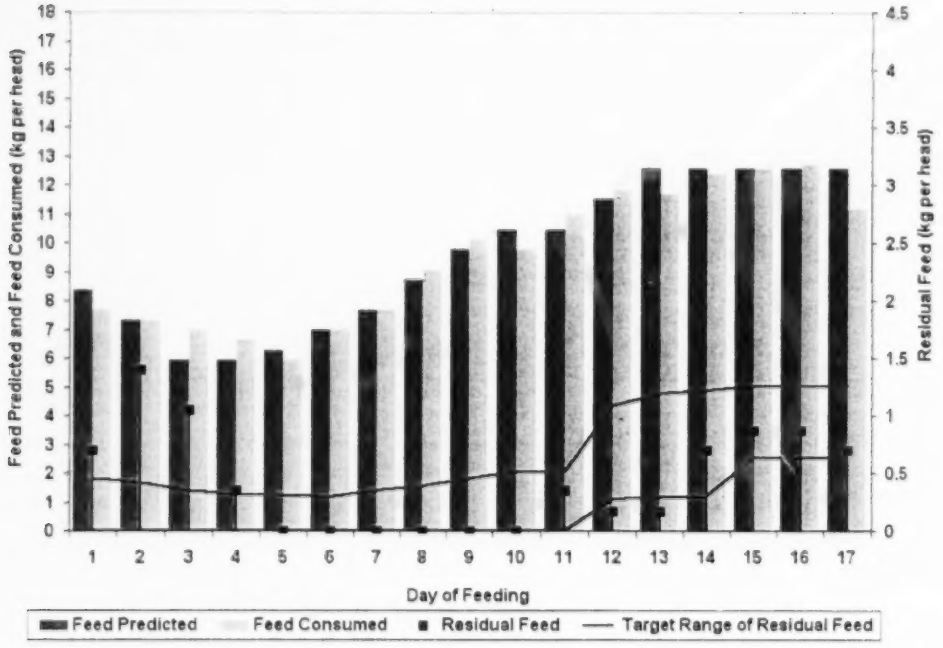


Figure G6: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 8.

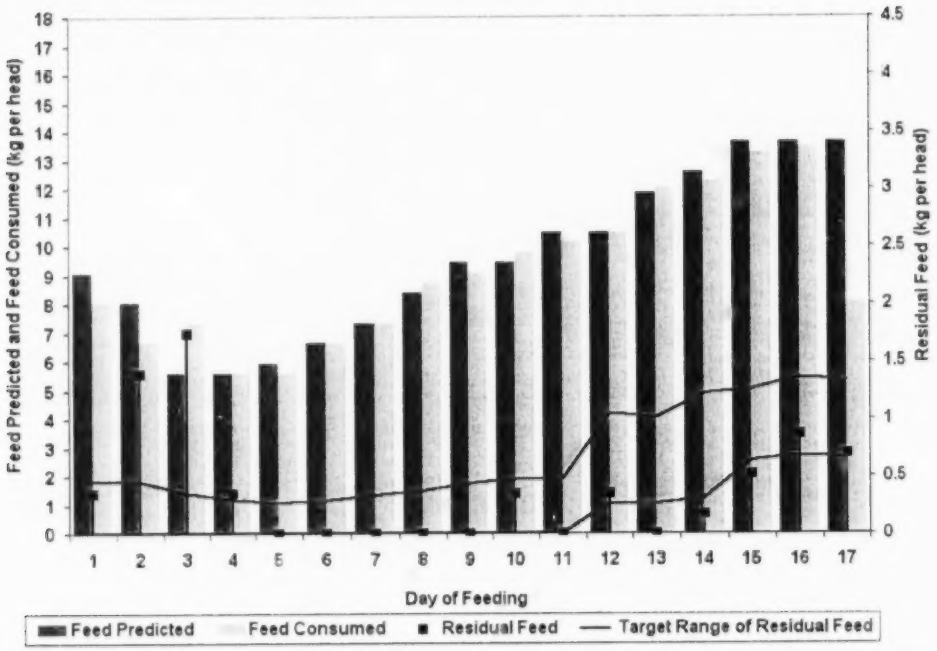


Figure G7: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 9.

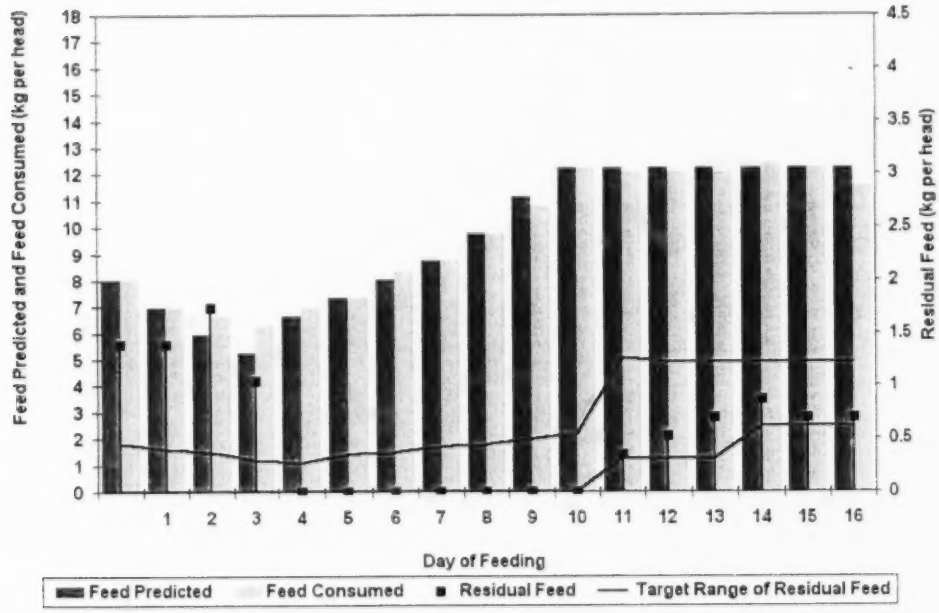


Figure G8: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 10.

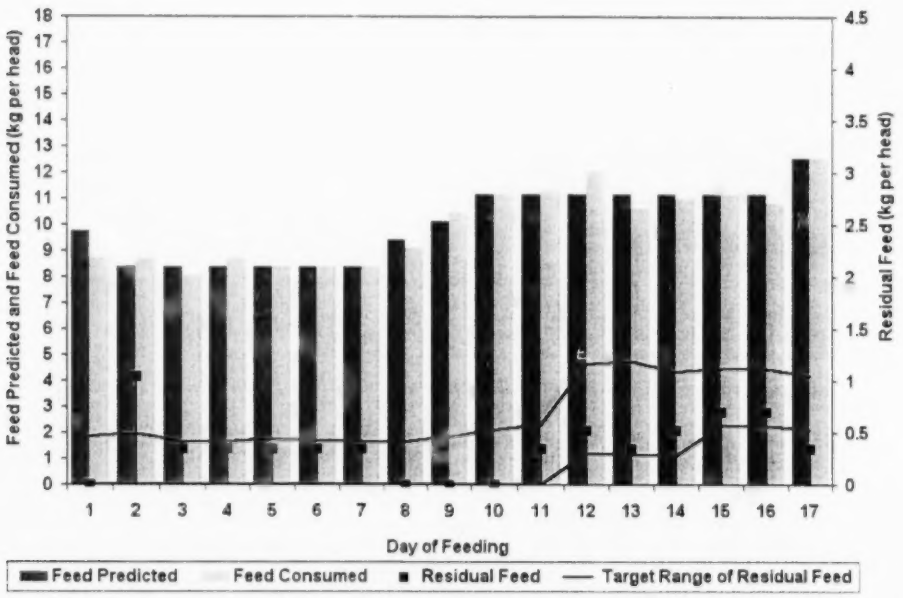


Figure G9: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 11.

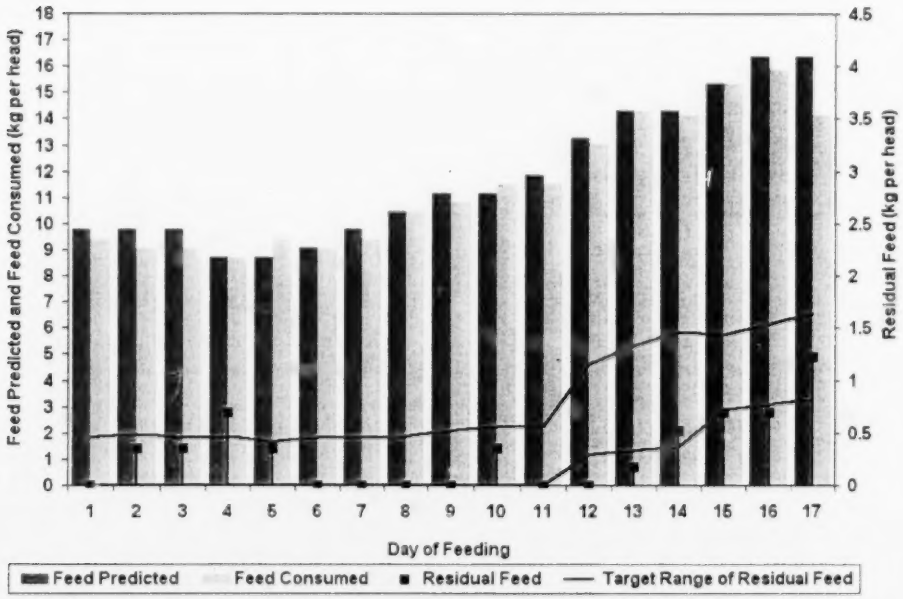


Figure G10: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 12.

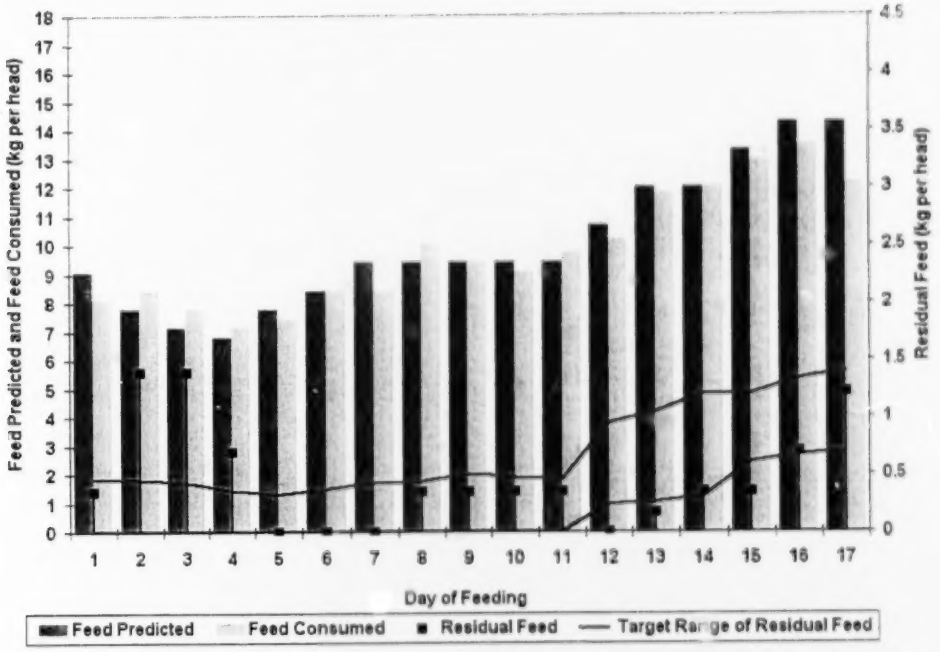


Figure G11: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 14.

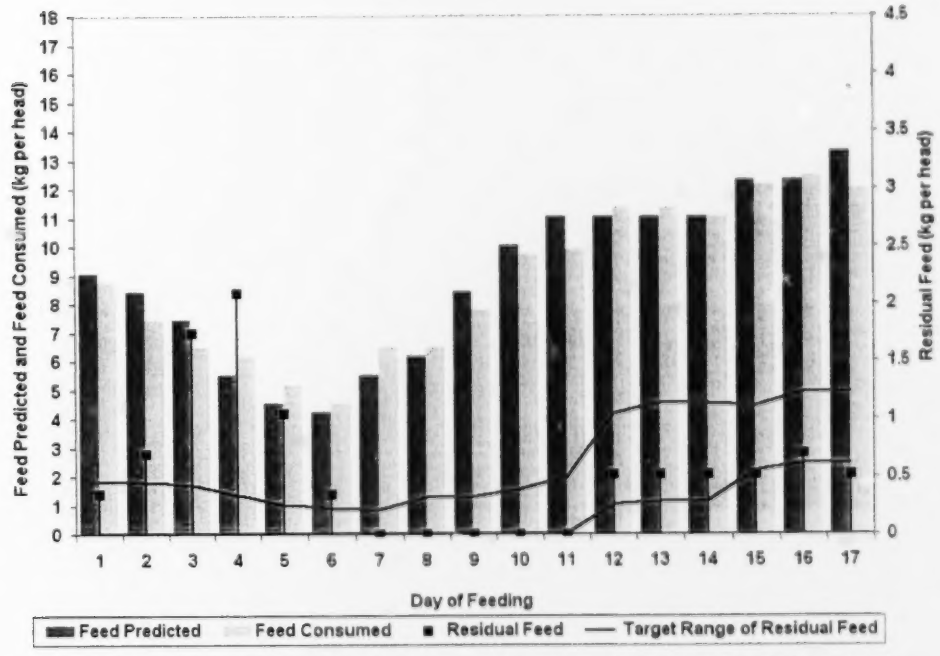


Figure G12: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 15.

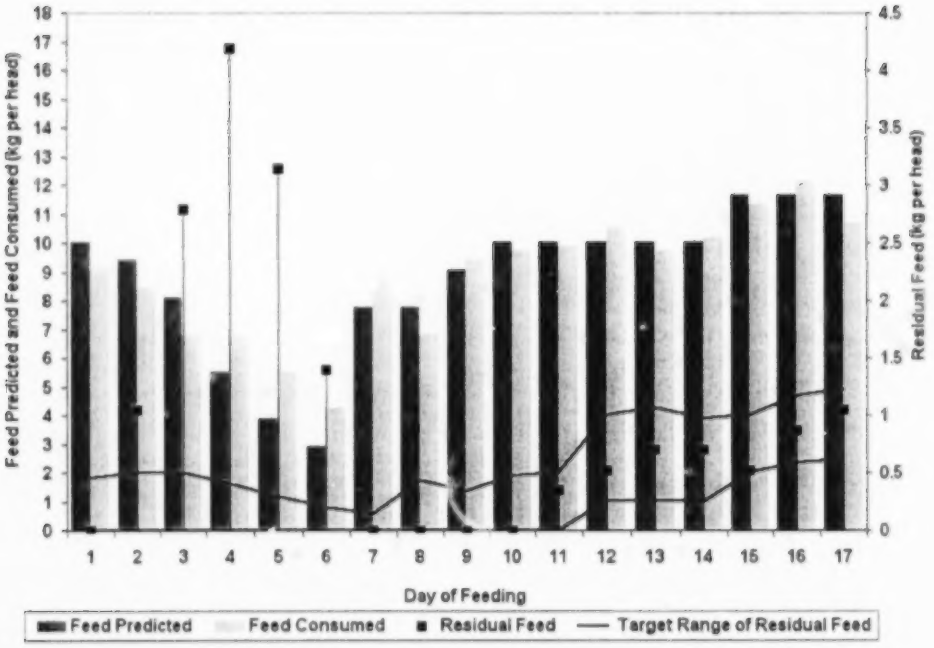


Figure G13: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 16.

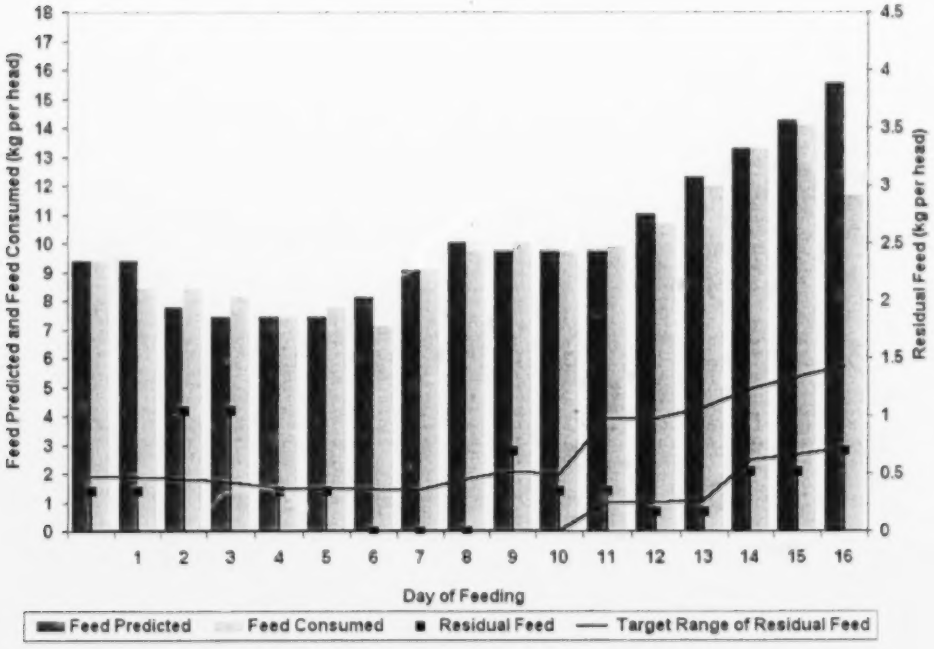


Figure G14: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 17.

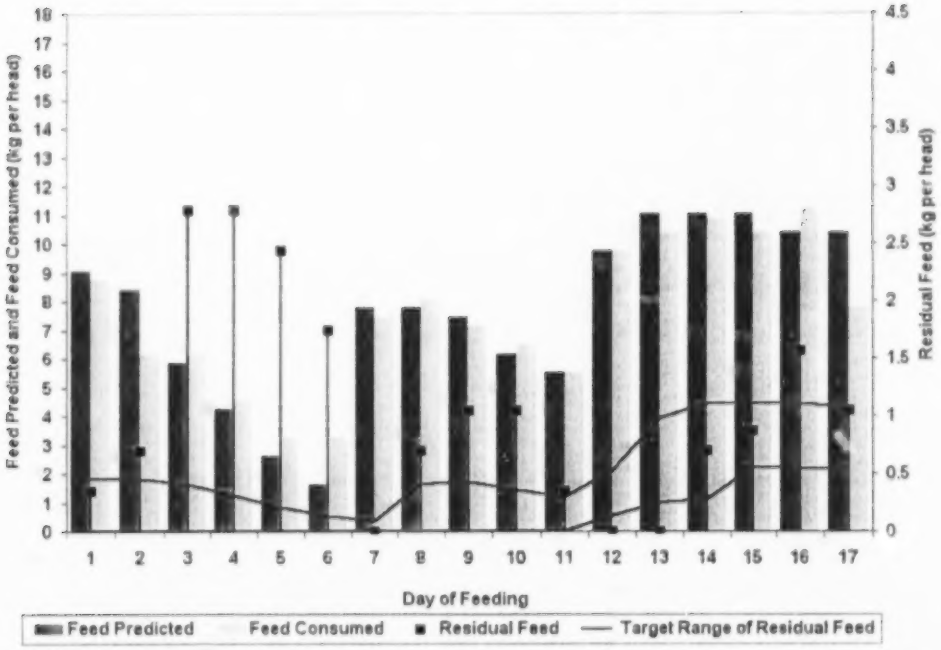


Figure G15: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 18.

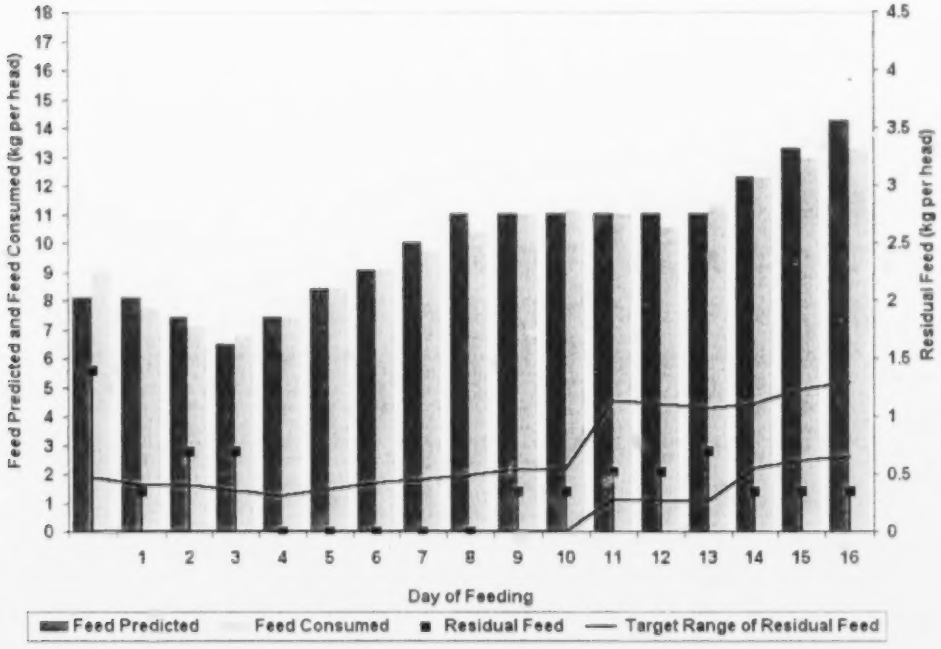


Figure G16: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 19.

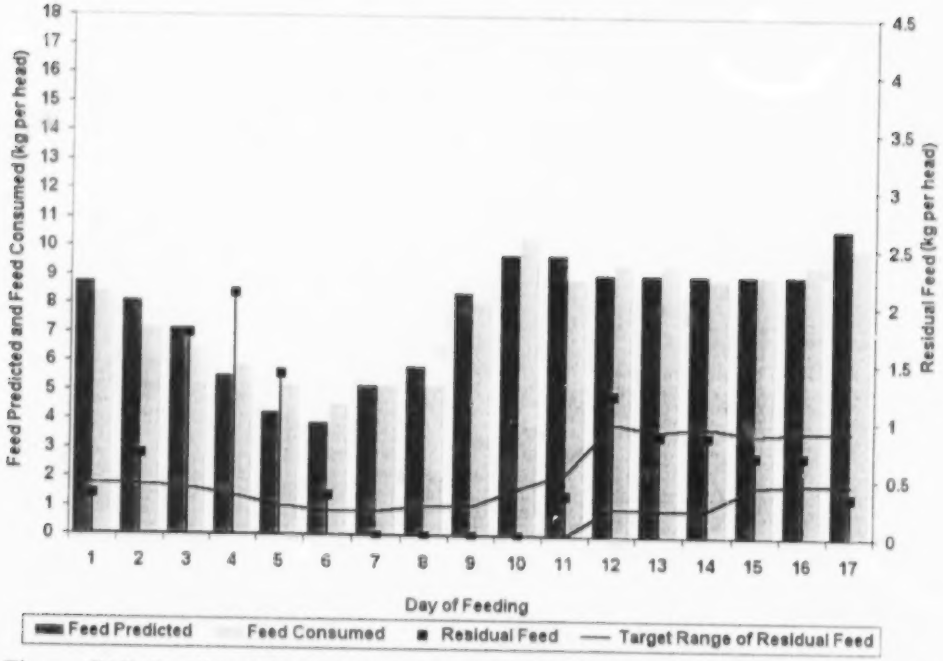


Figure G17: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 20.

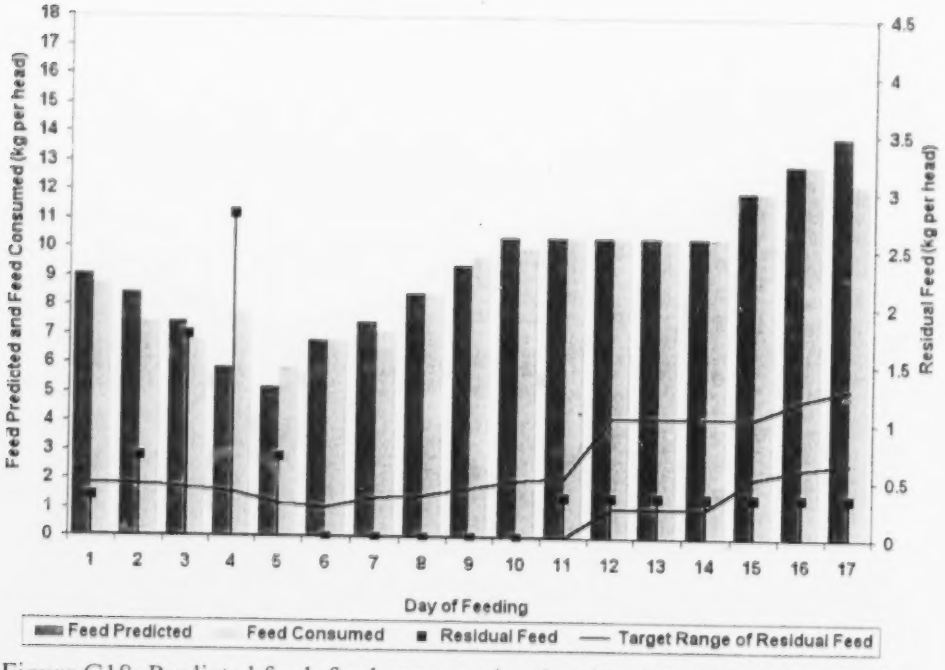


Figure G18: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 21.

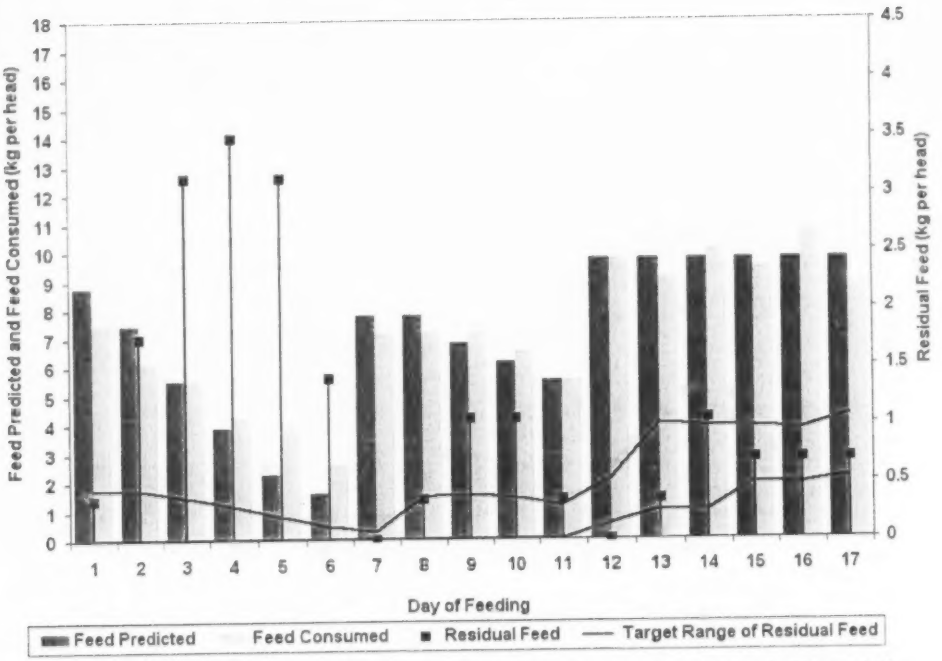


Figure G19: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 22.

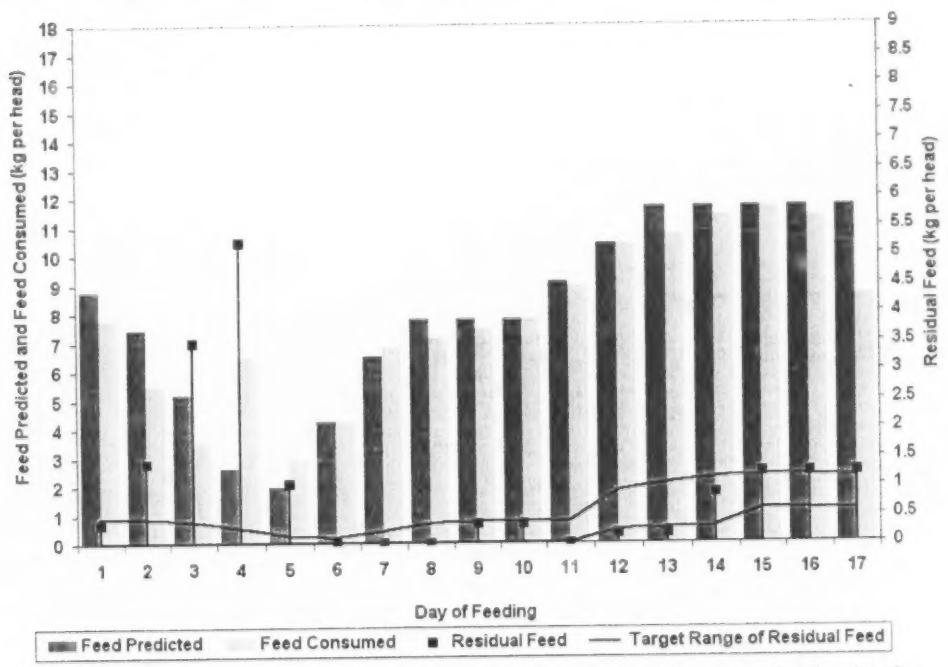


Figure G20: Predicted feed, feed consumed and residual feed (as-fed basis) for per head Pen 23.

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